

FOOD AND AGRICULTURAL RESEARCH COUNCIL

P R O C E E D I N G S

**THIRD ANNUAL MEETING
OF
AGRICULTURAL SCIENTISTS**

REDUIT, MAURITIUS, 17-18 NOVEMBER 1998

October 1999

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P R O C E E D I N G S

Third Annual Meeting of Agricultural Scientists

University of Mauritius
Réduit, Mauritius, 17 - 18 November 1998

Organised by

The Food and Agricultural Research Council (FARC)

in collaboration with

The Agricultural Research and Extension Unit (AREU)

**The Agricultural Services, Ministry of Agriculture,
Food Technology and Natural Resources**

The Albion Fisheries Research Center (AFRC)

**The Faculties of Agriculture and Science,
University of Mauritius (UOM)**

The Mauritius Sugar Industry Research Institute (MSIRI)

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PARTICIPATING INSTITUTIONS 1998

Agricultural Research and Extension Unit (AREU)

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The Agricultural Research and Extension Unit functions under the aegis of the Food and Agricultural Research Council as from July 1995. The main objective of AREU is to serve its clients through excellence in cost-effective high quality research and extension and to meet the policy requirements of government. AREU has responsibility for livestock and all crops excluding sugarcane.

Agricultural Services, Ministry of Agriculture, Food Technology and Natural Resources

Réduit Mauritius

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The Agricultural Services of the Ministry of Agriculture, Food Technology and Natural Resources started life as the Department of Agriculture in 1913 itself taking over from the *Station Agronomique* created in 1893. It is the regulatory body of the Ministry and provides a number of services to the agricultural community.

Albion Fisheries Research Centre (AFRC)

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The objectives of the Albion Fisheries Research Centre are to carry out research and development activities with a view to increasing knowledge on fishery resources within the fishing limits of Mauritius and to provide a basis for their sustainable development and management.

Food and Agricultural Research Council (FARC)

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The Food and Agricultural Research Council was created in 1985. Its main objective is to promote, harmonise and co-ordinate research activities in agriculture, fisheries, forestry and food production in line with government policy and to ensure that the farming community draws the maximum benefits from such research.

Mauritius Sugar Industry Research Institute (MSIRI)

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The Mauritius Sugar Industry Research Institute is a statutory body created in 1953 with mandate to promote by means of research and investigation the technical progress of the sugar industry. It also carries out research on foodcrops that are grown in association with sugarcane.

University of Mauritius (UOM)

Réduit Mauritius

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The University of Mauritius was founded in 1965. While training remains one of its important mandates, it also focuses on research in diverse areas which include agriculture and allied subjects.

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FOREWORD 1998

This third Annual Meeting of Agricultural Scientists of Mauritius (AMAS), formerly organised as part of the World Bank assisted Agricultural Management Services Project is now funded by the Food and Agricultural Research Council.

It was decided to continue encouraging younger scientists from the five main agricultural research institutions namely the Agricultural Research and Extension Unit, the Agricultural Services of the Ministry of Agriculture, Food Technology and Natural Resources, the Albion Fisheries Research Centre, the Sugar Industry Research Institute and the University of Mauritius to present papers at this meeting. As a result thirty two papers were received and they are published in the proceedings. In addition five papers presented during poster sessions are also included in the proceedings. The keynote address is dedicated to the memory of late Mr Maurice Paturau, Coordinator of the Joint Economic Council.

We are most grateful to the staff of FARC and to all those who in one way or another have contributed to the success of the meeting.

Jean Alain Lalouette

Director General

WELCOMING ADDRESS 1998

Alain Noel G.O.S.K., C.B.E.

CHAIRMAN, FARC

The Honourable Minister of Agriculture, Food Technology and Natural Resources
Excellencies, of the Diplomatic Corps
Members of the National Assembly,
The Permanent Secretary, Ministry of Agriculture, Food Technology and Natural Resources
Distinguished Guests,
Fellow scientists
Ladies and Gentlemen

I have pleasure, again this year, to welcome you to the annual meeting of agricultural scientists (AMAS) organised by the Food and Agricultural Research Council, in partnership with the Agricultural Research and Extension Unit, the Agricultural Services, the Mauritius Sugar Industry Research Institute, the University of Mauritius and the Albion Fisheries Research Centre, which I am pleased to welcome among us. This is the third meeting of its kind, and as planned, is set to become an annual feature.

This gathering provides a good opportunity for Agricultural Scientists to meet one another and share their research results with the agricultural community. I am pleased to record the successful response we have had to the call for papers. It is neither reasonable nor desirable to present all the papers received; otherwise this two-day meeting would have been unduly hectic or variable in quality. I have to thank members of the refereeing team who have helped us in the selection of papers. It is our objective to continually raise the standard of papers presented at future conferences. AMAS has so far been opened to local scientists but it is proposed to give it a regional and eventually an international touch.

C'est avec plaisir que nous accueillons parmi nous le représentant du CIRAD de la Réunion qui nous fera un exposé sur la recherche agricole à la Réunion. Je souhaite la bienvenue à Monsieur Bernard Reynaud, et espère que ce n'est que le début d'une longue et fructueuse coopération entre nos institutions.

Our keynote address this year is dedicated to Maurice Paturau whose memory we wish to honour for his contribution to scientific research related to the sugar industry, and particularly its by-products. The subject of this address "Sugar cane and its Co-products" pays tribute to his efforts in this field. It is with great pleasure that I welcome Dr Oscar Almazan, General Vice Chairman of the International Society of Sugarcane Technologists (ISSCT), and President of the Cuban Society of Sugarcane Technologists, to deliver this lecture. I am grateful that he has accepted our invitation and has travelled from Cuba to be our guest.

A special word of thanks to the organising committee, which has spared no effort to make this conference a success.

Ladies and gentleman, Thank you for your presence at this meeting

MINISTER'S ADDRESS 1998

Dr. The Honourable Arvin Boolell **Minister of Agriculture, Food Technology and Natural Resources**

I am pleased to be associated with the Third Annual Meeting of Agricultural Scientists.

The results of your deliberation will undoubtedly influence many decisions and policies related to agriculture and will certainly be a major determining factor when the governing boards of the different institutions represented here decide to shape up their action plan for coming years. Your task is a noble one. You are called upon to contribute directly to nation building, in raising levels of nutrition and the standards of living, in securing improvements in the efficiency of the production and distribution of all food and agricultural products. However, we have to ensure that all members of the agricultural community, both large and small, both rich and poor share the benefits of the application of your research.

In this regard, the synergy private-public sector is of vital importance. Your presence, ladies and gentlemen, confirms your commitment and interest in research undertaken by our national institutions. The results of the research, their implementation and the feedback from the grassroots will undoubtedly create the much-needed public private sector synergy.

It is befitting to attribute the keynote address to be delivered by Dr Almazan to the late Maurice Paturau. Mr. Paturau will be remembered as a bold innovator, and a renowned scholar.

It is certainly necessary that new and effective action should be carried out using the relative limited means available to us. For utilising scarce and limited resources allocated to research, we need to tread cautiously and adopt a pragmatic approach. Overlapping and duplication of research should be avoided at all costs. Research must be based on a careful identification of those areas, which show enough promise for improvement in both the medium and the long term. All of us reckon that the ultimate impact will depend on the overall research facilities. Priorities should be directed not only to national needs but also to our neighbours in the region. I welcome the participation of scientists from *La Réunion*. My hope is that the next meeting of AMAS shall be enriched by the participation of the Indian Ocean Rim and SADC countries. This action will go a long way in consolidating regional solidarity.

We, in this region, must be aware of the limits and constraints to our research capacity. We need to identify our requirements and to mobilize resources for institutional and manpower development. The activities within existing bilateral and multilateral regional cooperation networks and the establishment of additional ones should help to make optimum use of scarce research resources as it is not possible for each single country to cover entirely all its research needs. In all these fields, Government looks to the scientific community gathered here to provide guidance for its future action.

The myriad of institutions involved in research in Mauritius has to develop a strategy paving the way for Mauritius to be reckoned as a knowledge base in science and in agriculture in the region.

We must all gear our programs to accommodate the opportunities, which Mozambique is presenting to us. Our investors there need scientific backup. In this regard, linkages and working relationships have to be established urgently with sister institutions of Mozambique. Let me recall that the Mozambique issue is a national issue and a collaborative effort of all our institutions in this direction is crucial. My other humble request to agricultural scientists is to emphasize approaches which are not capital intensive and to give due attention to research priorities such as stability of production and secondly to tolerance of crops to the climatic and environmental stresses and changes in the wake of the global warming up.

In the past, the benefits of research and agricultural technologies have been developed and deployed often with little or no consideration of the impact on the agricultural community, their basic needs and income. Problems related to farm households, gender relationships, consumer preferences and similar issues were seldom considered. But the climate of opinion to day has shifted. The prospective impacts of new technologies are matters of strong public concern. There is a strong recognition that the research community should be aware of the likely impact of its new discoveries. The potential socioeconomic consequences of new technologies should be considered when research priorities and goals are formulated. It will therefore be necessary to monitor and assess not only scientific progress and policies but also the socioeconomic impact of new biotechnologies applied in agriculture.

These are some of the considerations, which you may wish to take into account in the action plan of your respective institutions. I know you would be the first to say that agricultural yields and aggregate output should not be seen as our only objectives. Other objectives such as stability of production systems, ecological sustainability, protection of the environment, food quality or social justice are of equal or even higher importance. Research must benefit both the producers and the consumers. Science must assist in overcoming poverty and narrowing the differences in the quality of life of each, the rich and the not so rich. The aim is a better life for all, for present and for future generations.

I wish you a successful meeting and assure you of my support and my keen interest in your results.

Thank you.

**MAURICE PATURAU MEMORIAL LECTURE
KEYNOTE ADDRESS 1998**

THE SUGAR CANE, ITS BY-PRODUCTS AND CO-PRODUCTS

O Almazan, L Gonzalez and L Galvez
Asociacion de Tecnicos Azucareros de Cuba

ABSTRACT

*I came here to pay my respect to a man I met twenty five years ago and who became a real institution in the field of sugar cane by-products; a direct and outspoken man, a true scholar in the knowledge of this line who gave the sugar industry the strength and the necessary buffer capacity to overcome its periodic crises. But above all I want to give my respect to a gentleman, to a man of high intellectual integrity and profound humility, a combination that only the very few can have. I came here to honour this good and admired friend in a way he would have liked to be remembered talking about sugar cane by-products. My address: **The Sugar Cane, its by-products and co-products**, is dedicated to the memory of the very respected and never to be forgotten Maurice Paturau.*

Keywords : sugar-cane, by-products, energy-sources, renewable-energy, biotechnology, sugar-industry, diversification

INTRODUCTION

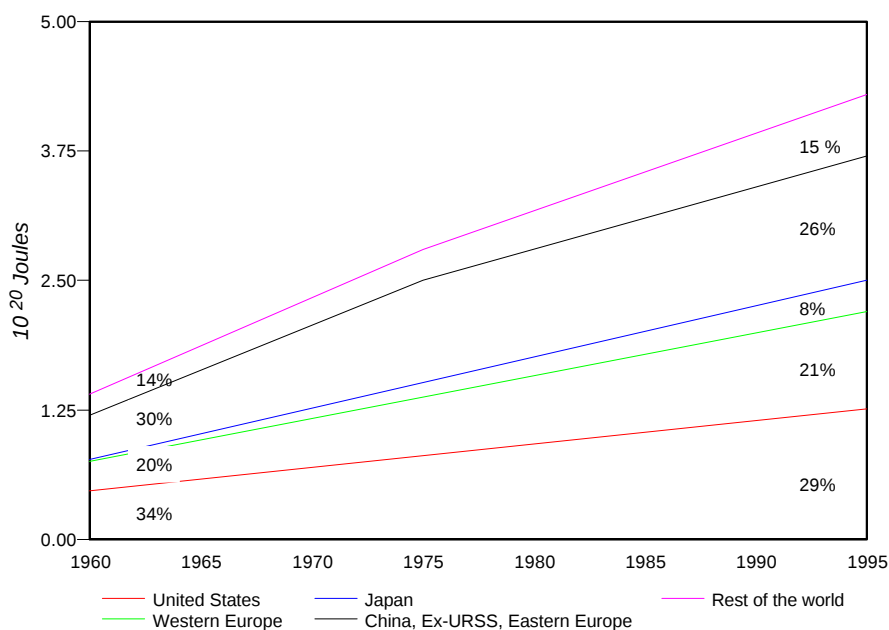
At the beginning of this century world sugar production, from all different sources, amounted to 12 million tonnes and per capita consumption was 8 kg. Production will have grown tenfold and per capita consumption by three times, by the end of this century. Even with the appearance of new sweeteners on the market, sugar is still the most widely used caloric food in all countries, especially among those of lower income. Its outstanding value for health improvement becomes more evident everyday, mainly when it is used in the less refined form.

The international sugar market will show different characteristics in the next century: It will be a deregulated and highly competitive market; exports will be concentrated, with more than 70 percent accounted for by the five leading exporters, the European Union taking the first place. Eighty percent of imports will be made by the less developed countries compared to only 30 percent in 1970. Alternative sweeteners will slowly continue to increase their presence with an expected 16 percent of the market in year 2000 compared to 13.5 percent in 1994 - 95. Prices are forecasted to be at a level of 22 - 27 US cents per kg (10 - 12 US cents per pound) with a total trade volume of 28 - 30 million tonnes in the year 2000. World food demand at the beginning of next century will be twice as much as three decades ago; less developed countries will need to increase their production by one and a half times to simply meet the requirements of their increasing population.

The energy problem is another issue that will have to be faced and will require more emphasis in planning for next century. World energy consumption (**Figure 1**) has grown to such an extent that what is spent on oil during this decade will be as much as all the expenditures on oil over the last 100 years. It is in this context that the rationality of the sugar industry diversification must be defined. New trends in biotechnology, the search for new materials, the preference for renewable products of natural origin and other development opportunities are emerging that could raise the added value of raw materials from 5 to 20 times, depending on process complexity and efficiency.

In this paper we present a summary of the evolution, present status and strategies for the development of sugar industry diversification.

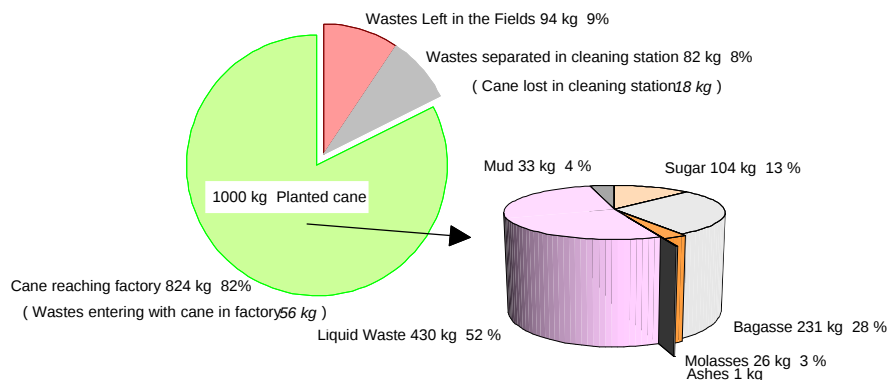
Figure 1. World energy demand by regions



Sugarcane as a raw material

Sugar cane has one of the most efficient photosynthetic mechanisms, among commercial crops; this allows it to fix almost 2 - 3 percent of radiant solar energy and transform it into green biomass. This high photosynthetic capability also allows it to show a high coefficient of CO₂ fixation, comparable to the moderate climate zone woods. This contributes to the decrease of the greenhouse effect.

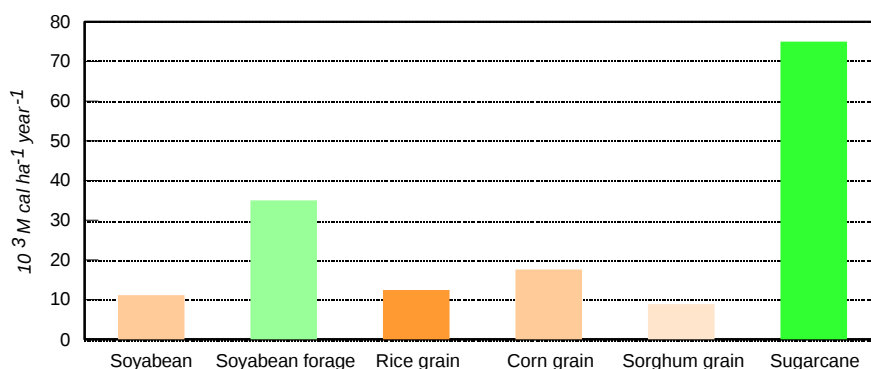
Figure 2. Balance of cane products and by-products of harvest and industry



From cane harvest and processing, it is possible to obtain 8 products and by-products (Figure 2) which are potential raw materials for the extractive, chemical and biochemical industry. The various sugar-producing countries currently produce more than fifty commercial products.

One hectare of cane may produce 100 tonnes of green matter every year, which is more than twice the agricultural yield of most other commercial crops. Its total dry matter content has a fuel equivalent of about 10 to 20 tonnes of oil. As metabolic energy carrier for animal feeding, each cultivated hectare delivers 75 000 million calories each year, equivalent to more than 8 times the yield of other fodder crops (Figure 3).

Figure 3. Potential calorific value produced by different crops for animal feeding



A special attention in the diversification strategy must be given to the efficient use of the energy potential of sugar cane, which may be transformed into approximately 1 tonne of oil equivalent for every tonne of sugar produced. A typical (traditional) sugar cane factory uses inefficiently all the available energy in its bagasse but it has been shown that with a properly designed process, oriented to energy saving, it is possible to operate with only 50 percent of that energy. Sugar cane processed using chemical and biotechnologies, can produce a high number of products, and is surpassed only by those obtained from petrochemistry. Practically all products and by-products obtained from sugar cane may become substrates for liquid or solid-state fermentation processes; using available second and third generation biotechnology a significant number of production processes could be developed. The agro industrial character of sugar cane processing allows for an industrial development in which all available wastes and resources could be managed profitably while avoiding pollution of the environment. Sugar cane producing countries, have a significant advantage in possessing a renewable raw material, which can be used in human and animal feeding, and in the production of basic chemicals, with a yield not equalled by any other plant. Furthermore, sugar cane has energy delivering capacity equivalent to five times that used by the crop. All these factors taken together and the possibilities offered by further genetic improvement, turns sugar cane into the ideal crop for the next century.

Bagasse fibre as a raw material

Bagasse obtained as a by-product of sugar cane processing, is composed of fibre, pith, non-soluble solids and water; fibre represents about half of all components, and includes cellulose, hemicellulose and lignin of low molecular weight. Its morphological structure is not strong in comparison with other fibres like those of wood; its advantages are shown during chemical and mechanical treatments, since it does not have to be submitted to severe processes. Another important advantage is that it is directly obtained and concentrated in the sugar factory as a process by-product, thus simplifying handling and transport operations. Every year, more than 200 million tonnes of bagasse are obtained together with sugar, in all cane producing countries, 95 percent of which is used as fuel in the mills, which represent a saving of about 40 million tonnes of oil.

Pulp and paper, boards, furfural and animal feeds are among the main products obtained from bagasse not used as fuel. The most widespread use of bagasse around the world is in the production of pulp and paper. There are about 90 factories in all, of which three-quarters are established in Asia, Oceania and the Middle East, delivering up to 2.5 percent of the total world production. Intense exploitation of wood has caused depletion of forest reserves. This has triggered a trend to decrease this exploitation, to implement reforestation policies and renew interest in tropical woods and annual plants to be used in combination with traditional wood fibres. It becomes evident that it will be necessary to rely on other fibre sources to fulfil the forecasted demands for the next century. Among alternative fibres, it is accepted that bagasse is one of the best due to its quality, cost and renewable character.

Bagasse fibre can be used at present as an important component in printing and cultural paper, but its use for industrial paper is still limited. One hectare of sugar cane can produce, annually, about five

tonnes of fibre for pulp and paper production, twice as much as that produced by one hectare of wood with the same management. The renewal period is fifteen times shorter for sugar cane.

New developments in pulping are expected to include a first step consisting of a microbiological treatment for fibre preservation and its partial or total delignification in the unavoidable storage stage. Consequently the rest of the process will have lower energy and chemicals demands. Bleaching processes will turn to gas phase, aiming for better yields and the elimination of pollutants in current processes.

Mechanical and thermo-mechanical pulping will become more popular in paper production with a decreasing share of traditional chemical pulps. More chemicals will be used in industrial paper production in order to obtain the desired specific properties. The paper industry will maintain its trend of increasing the waste paper recycling in order to reduce fresh fibre addition in the feed and as a contribution to the rational use of natural resources. New technologies will decrease the present demand of water to one third, reducing in the same proportion the pollution load of the wastes.

Fibres are also used for the production of bagasse boards, a production which is expected to increase for the same reason because of the need to preserve forest reserves, promoting the search for new alternatives for both types, particle and fibre boards and new types as the MDF boards. Moulded elements, produced by similar technologies, as those of boards will fulfil the quality requirements of a great deal of industry and home products

Composites of natural fibres

The composite is a mixture of dispersed particles held together by a bonding agent of inorganic or organic origin.

Bagasse is not only a renewable source of natural fibres, but can also be transformed into furfural, which may be the starting point of a large number of resins.

There are composites of natural fibres for the automobile industry, for textiles, for construction materials, with inorganic and organic matrices and more recently, recycled composites made of natural fibres bonded with thermoplastic polymers.

Boards and moulded elements will show specific properties for different purposes: furniture, liners, walls or construction forms. These products will be designed and produced in such a way that they will be able to substitute wood in up to 90 percent of its uses. They will be finished with radiation-polymerised resins, which will result in a much better quality than that reached today and an improved surface resistance. These polymers used for bonding and finishing may be produced from other products and by-products such as furfural or sucrose; the lignin present in bagasse can also be used as the bonding agent. Properties of lignin will be used for fulfilling demands of moulded elements for domestic products, furniture, the automobile industry, and packing materials.

Chemical and biotechnological development of cane sugar by-products

Most chemical firms have based their production mainly on petro-chemistry, while other alternatives like those offered by sugar cane, have received much less attention. The economical causes for this situation are expected to change in the future.

Considering all of these sources, different possible alternatives for the production of organic and speciality chemicals and related products could be mentioned.

Sources for chemical and biotechnological products from the sugar industry

<i>Sugar cane</i>	<i>Pith and bagacillo</i>
<i>Lignocellulosic residues from the crop</i>	<i>Mud (cachaza)</i>
<i>Intermediate flows of process</i>	<i>Fusel</i>
<i>Molasses of different purities</i>	<i>Wastes from chemical plants</i>
<i>Sucrose wastes from distilleries</i>	
<i>Bagasse wastes from yeast production</i>	

Biotechnologies of second and third generation have made available conventional and new technologies for the production of: amino acids, vitamins, organic acids, solvents, microbial polymers, proteins for human and animal consumption, enzymes for industrial use, alcohol and co-products industry and such microbiological processes as: silage, biologic treatments of lignocellulosic residues, biopulping and biobleaching processes, anaerobic digestion of waste streams, and other alternatives. In addition, more sophisticated technologies are available for their application in the pharmaceutical industry. It may be considered that all sugar cane by-products could be used as substrates for liquid or solid-state fermentation opening a wide range of possibilities for production based on biochemical processes.

Alcohol as automotive fuel

Brazil transforms sugar cane into about 12 x 10⁹ litres of alcohol, one fifth of which, in anhydrous form.

The Proalcohol Program reached its 20th anniversary facing a crisis of official support, after an investment of USD 11 000 million and decreasing imports of gasoline of more than USD 27 000 million during the past two decades.

Out of 348 distilleries only 298 are still in operation, resulting in the importation of 1 000 million litres of ethanol and 800 million litres of methanol.

The supporters of the Proalcohol Program constitute a powerful lobby using the very reasons which led to the creation of the program: the economic value of this industry and its contribution both as a renewable source of energy and as a solution to environmental pollution in big cities.

No matter what will be the outcome of this conflict, it will bear an influence on both the alcohol and sugar markets.

The development of a chemical industry from ethanol or *alco-chemistry*, as an alternative or complement to petro-chemistry could allow the production of basic products in all industry branches. The two most developed alternatives are those following the ethylene and acetaldehyde paths. The first one produces a great variety of plastic materials in great demand and the second one develops acetate compounds, which are the basis of the paint and varnish industries. Even when high efficiency and relative low cost in petro-chemical production are perfectly known, the complexity of plants, their economies of scale and high investment costs set true limits in those countries with insufficient financial resources, limited markets or technological development, and little or inexistent oil resources. Alco-chemistry technologies are available and operating at industrial scale in some countries. A waste product from alcohol production: fusel oil, a mixture of isomers of amylic and propylic alcohols, could be recovered. Isoamylic alcohol, amylic alcohol, n-butanol and other compounds may be separated through distillation showing some economical advantages due to low costs. Furfural is an aldehyde produced by the acid hydrolysis of the pentosans present in different crops. Cane bagasse is one of the best raw materials for this production. Low toxicity of fufural makes it a valuable product for the chemical industry from which the following could be derived : resins and plastics, pharmaceuticals, fufuryl alcohol and its resins and monochloroacetic acid, herbicides, tetrahydrofufurylic alcohol and maleic anhydride, tetrahydrofuran.

Based on sugar cane by-products some alternatives for herbicides production could be mentioned: the first from furfural, and some others based on acetic or propionic acids possibly derived from furfural or alcohol production wastes. The option of new herbicide production starting with furfural has been studied for many years. The synthesis of different products, which passed the screening tests with positive results, has been successfully achieved. The results however can only be considered in the medium or long term because of the high costs of development. Acetic acid obtained from furfural distillation, and propionic acid from alcohol distilleries wastes may become, in the short term, raw materials for conventional products such as 3-chloroacetic acid, monochloroacetic acid or chloropropionic acid. Cellulose in bagasse could be used for the development of a cellulose based chemical industry. Cellulose fibres obtained from bagasse, showing high modules of wet resistance, could substitute up to 60 percent of the fibres derived from cotton cellulose used today in commercial textiles.

Fibrana production processes use directly wet pulps and accelerated ageing of alkali cellulose. Fibres are treated in processes, which allow them to reach high modules of wet resistance, similar to those of cotton. Based on chemical pulps, other high demand by-products of cellulose can be produced such as: cellophane, carboxymethylcellulose, cellulose acetate, cellulose nitrate, cellulosamide, chromatographic bases and others. Most of these products would be manufactured in a combined way through the integral use of the installations.

For the production of chemicals through thermo chemistry there are three main options: gasification, pyrolysis and liquefaction. Studies up to the present show that the most interesting alternative is that of gasification for production of synthesis gas as a way which can be converted to methanol, ammonia and ethylene. At medium and long terms, some of these products may be feasible but these alternatives are still in an experimental stage.

Lignin is the second most abundant substance in nature, and at the same time one of the least exploited up to the present. A great potential exists for its use in the chemical industry. It is technologically feasible to obtain phenols for production of adhesives, resins, fungicides, veterinary products, insecticides, and carbon. Lignosulphonates are present in black liquors of sulfite processing. It is a very important product in the artificial board industry as a filler and / or additive in the urea-formaldehyde resin, and for reducing costs and improving some board properties

Sucrochemistry as an alternative use of sugar

During the nineteen forties, technological processes using sucrose as raw material for chemical production started to be referred to as *sucrochemistry*. In the last five decades, about 10 000 technically feasible products have been developed from sucrose at laboratory and pilot plant scale. Only about one hundred have also demonstrated their economic feasibility and are being produced on a commercial scale.

Due to its high production level as a commercial, crystalline product, sucrose is one of the most interesting substrate for the development of new chemical and microbiological technologies. The presence of 8 hydroxyl groups allows broad possibilities of chemical bonding becoming a potential source for the production of chemicals with quite different properties, through degradation, synthetic and microbiological reactions. Through controlled degradation reactions, it is possible to obtain an important number of chemicals. However only through catalytic hydrogenation it has been possible to produce such important commercial products as: fructose, sorbitol and mannitol. Through chemical synthesis and based on the high solubility of sucrose in water and the presence of the high number of hydroxyl groups, it has been possible to produce: ethers, esters from fatty acids, polymers and resins, among the most important, some of which have reached commercial production. These routes show the drawback that reaction products are not stable in those solvents in which sucrose itself is, turning separation and purification stages very complex and expensive.

Sucrose ethers are obtained by the substitution of hydrogen ions by alkyl or aryl groups. The properties of resulting compounds are not attractive from a commercial point of view, limiting the development of this alternative; only urethanes have found an industrial use and a market. Used in rigid foams (polyurethane) they offer good potentiality based on their prices and quality.

Fatty acid esters require most intense research work and a significant number of different processes. Some American, Japanese, English and French firms deliver different products to the market, turning this alternative as the most important, with the highest commercial potential.

Polyesters Of Fatty Acids are receiving special attention in the last years because of their use in hypo caloric diets, and as blood cholesterol depressors. Some sucrose esters have shown their properties, when used in low concentration, as antimicrobial agents, inhibiting bacterial growth. Cosmetic formulation with *sucrose esters* has had good acceptance, due to their dermatological properties and their innocuity. In the same way, they have been used in biodegradable detergents, for widespread use extracting spilt oil from the sea and other aqueous deposits. The alternative of microbial transformations of sucrose molecules allows the production of different biopolymer such as dextran and xhantan; both are products used in foods, pharmaceuticals and in oil extraction. The biopolymer polyhydroxibutirate showing similar properties to those of polypropylene has not been able to compete with the latter due to high production costs.

Based on sucrose, some other sweetening agents showing special properties have been obtained becoming potential alternatives for sucrose. Among the most important the following could be mentioned.

Chlored chemicals obtained through selective substitution of hydroxyls with chlorine atoms are often products sweeter than sucrose. But there are others, which are extremely bitter, showing specific properties. The use of these compounds awaits approval by medical authorities.

Leucrose is a sucrose isomer with less sweetening power, innocuous, acceptable by diabetics, approved as a human food. It is also used as basis for production of special purpose tensoactives.

Sucralose was developed two decades ago through a modification of the molecular structure of sucrose. It is 600 times sweeter and shows similar flavour characteristics. From the point of view of human health it does not stimulate insulin formation, and it is eliminated from the human body without showing chemical changes, thus being a non-caloric food.

L. sugars or "lefties" as they are also called, are obtained through a change in hydroxyl groups. Their taste is close to that of sucrose while showing no calorific value, as they are not metabolised, and proceed through the intestines without chemical changes. Their production costs are high, and they have yet to complete tests for medical approval. Another product reached as sugar modification is *isomalt*, showing functional properties close to those ones of sucrose, with little commercialisation in Europe.

Substitute sweeteners for sugar

These products, born last century, show two main features: they are competitive in price and due to their low calorific value are good controllers of human weight.

Those nutritional substitutes may be sacharides or polyalcohols, which supply little or no energy to the organism while showing a sweet characteristic flavour. Those that are non-nutritional may be of synthetic or of natural origin; not giving up energy, they are used in beverage, food, and dairy products industries.

Tendency to use in sweetening; in mixtures however limited use, if production costs are not reduced.

It can be generally stated that sucrose alternative molecules, to be used as raw material for chemical production maintain the interest of researchers and producers due to the variety of applications that the products may have. Out of the three ways of reactions that sucrose could be subjected to degradation, chemical and microbiological, the latter appears to be the most interesting for the development of sucrochemistry.

Sources of animal feeding

The food, energy and environment problems are among the priority issues for the next century. Sugar cane production, followed by a rational diversification strategy, might have a significant place in this context because of its characteristic as a highly efficient system for solar energy fixation and transformation into green matter. This biomass is usable for energy and feeding purposes, while saving non-renewable sources of energy; it has therefore a positive CO₂ fixation balance. This statement is relevant to countries with tropical and subtropical climates where sugar cane can be grown and where socio-economical, technical and agricultural considerations will probably determine the optimal use of cereals mainly for direct human consumption. The indiscriminate extrapolation of feeding systems of moderate climate conditions to tropical countries will most probably result in a sub-optimal solution in the latter.

Under tropical conditions, feeding systems might rely on sugar cane as a source for 60 - 80 percent of ruminant and swine feeding requirements; this is true only if they are adequately supplemented with other products, which must be imported or made available locally. Sugar cane has a high percent of fibre with a low digestibility, which becomes a limitation for its use in monogastric animals. To overcome this deficiency and make an optimal use of the whole cane, alternatives have been developed for the latter's separation into three basic components: the crop wastes that may be used in its natural form or treated in a simple way for feeding bovines; the soluble sugars present in the juice to be used for poultry and swine, and lastly the fibre, after being subjected to simple treatments to raise its digestibility, to be given to ruminants.

Cane for animal feeding: main raw material alternatives

Whole cane conditioned for its direct consumption

Agricultural wastes as they are produced

Industrial by-products: bagasse, cush-cush, pith, C molasses and mud (cachaza) Process intermediate products, B molasses and diluted juices

Sugar as the commercial product, or of lower quality, or damaged

Proteins produced from fermentation of molasses or recovered in distilleries

The best way to use sugar cane for animal feeding is to use sugar, fibre or green mass depending on the species ability to more efficiently convert these products. The industrial processing of cane in the sugar factory, and the possibility of obtaining different products is probably the alternative showing the highest potential added value.

Feed characteristics required by different kinds of animals

Cattle: feeding may be based on fibres either from harvest wastes or from pith or bagacillo treated to increase their digestibility. Non protein nitrogen may be used up to a given level. Quality requirement of feed is not so high compared with other species.

Swine: Monogastrics show higher quality requirements of feed, not being able to metabolise fibres. An energy source must be provided such as final molasses which has its limitations or intermediate molasses; fodder yeast may be used as protein source

Poultry: It is the kind of animal with the highest and most complex requirements for feed quality. The energy sources used must show high values per unit weight and protein must be true protein showing a balanced amino acid profile. All vitamins required must be supplied.

An integral analysis of the main kinds of animals shows that the highest conversion of energy is accomplished in the production of swine and cow milk. In the case of protein conversion, meat production through bovines is the least efficient. Poultry show the fastest response with average mortality rates, but with high quality requirements in food, and the highest level of care. Swine show

the best conversion of food, productivity in newborn, high rates in weight increase, and a high yield of meat in the slaughterhouse, besides the possibility of producing meat derivatives showing higher added values. Ruminants become interesting to exploit the availability of low digestibility foods showing low values of true protein, even though daily gains will be lower than those obtained in moderate climates

The final decision of which alternative to follow in the production of meat and milk will be settled not only through the rational use of sugar cane, but also taking into account the local conditions to get the supplements required in the feeds, their prices and the markets to which the products will go.

Organic agriculture and sugar cane

The demand for agricultural products and foods obtained by ecological methods increase every day, building up new markets for those higher priced products. These products are obtained through what is known as *Biological* or *Organic Agriculture*. This system implies solutions to avoid the Earth's pollution, to provide better health conditions for producers and consumers, and to protect human life particularly in rural populations. A new food industry for the production of nutritive and healthy foods is emerging. Organic foods show maximum quality from the points of view of nutrition, and flavour, and have the better appearance. This system protects the environment and preserves fertility of soils and genetic diversity, through the optimum use of renewable resources, thus enabling sustainable agricultural development while avoiding the use of synthetic chemicals. Among the main practices for supporting this approach the following could be mentioned: bio-control, use of bio-fertilisers, green fertilisers, crop rotation, and composting.

Sugar cane by-products may find use in each one of these methods, as raw materials of different kinds and properties suitable for biotechnological transformation into valuable products, which can be used in cultivation of sugar cane and other crops. Interest in bio-control has increased lately, mainly due to the ever-increasing policies restricting the use of pesticides, and the search for techniques more friendly to the environment. Microorganisms may be used not only against other non-desirable microorganisms, but also against insects and plagues.

Experience exists in Cuba with the application of different agents for bio control in general agriculture, and especially in sugar cane, it encompasses the control of cane borer with the *Lixophaga* fly, and recently, the use of *Trichoderma* against most common fungus infections. At present, four different types of bio fertilizers are produced in Cuba; these are: *Azotobacter*, *Rhizobium*, *Bradyrhizobium*, and *Azospirillum*, the latter showing the best results in sugar cane, with yield increases of the order of 50 percent, depending on soil type and cane variety. Under Cuban conditions, the high level of harvest mechanisation, the industrial concentration of harvest wastes at the cleaning stations, and the availability of filter mud (*cachaza*) and bagasse at the factory makes composting very relevant. An adequate balance in formulation guarantees a complete and correct degradation of organic matter and substances to materials of humic nature.

Among micro-organisms producing positive effects in their interaction with plants, there are those able to produce growth regulators or phytohormones; these are chemical substances contributing to control the normal development of plants through a very fine balance between growth and the factors controlling it. Indoleacetic acid is used today in agriculture for different purposes, mainly in micro propagation of crops, particularly in sugar cane. Gibberellins, in particular gibberellic acid, are without doubt, the most important growth regulators produced by micro organisms, being given their production at world level and their broad application in agriculture. There are reports concerning their use for increasing yields in sugar cane, even though their use is not currently widespread for that purpose.

Sugar cane as energy source

Sugar cane dry matter when burned, produces 4000 Kcal per Kg (7200 Btu / lb.). One hectare of sugarcane can produce about 100 to 200 millions Kcal per year equivalent to about 10 to 20 tonnes of oil. Several studies have shown that the sugar cane industry can deliver not only surplus bagasse through efficient generation and use of steam, but also a surplus of 60 to 120 kWh of electric power per

tonne of cane, which can be delivered, to the grid. Most cane sugar factories all over the world use 550 to 650 kg of steam per tonne of crushed canes. For many years beet sugar factories, with a very similar process to that in use by cane sugar factories have been known to use about 320 kg per tonne of beet. Use of multiple bleeding in evaporation stations for heating and boiling, a high number of evaporation stages, up to six or even seven, the substitution of throttling valves by other systems, are solutions enhancing energy efficiencies. This has been tried in cane sugar factories, and values of the order of 370 kg of steam per tonne of cane have been recorded. This decrease in process steam may promote reductions in burned bagasse of about 25 percent. Cogeneration is the cheapest way of delivering surplus electrical power for other industrial uses or to the grid, while also delivering surplus bagasse. Currently, most boilers manufactured operate at a ratio of about 2.2 for steam generated to bagasse burnt (bagasse at 50 % moisture). The efficiencies of these boilers based on low heating values in the range of 80 to 84 percent, are better than those of most existing traditional boilers. Efficient use of process steam, dependent on high steam pressure and temperature in the steam generator, is not common in cane sugar factories with the exception of those in which big amounts of bagasse are used for other purposes. An unavoidable condition for economic development of by-products is to make use of the available co generated electric power while having simultaneously surplus bagasse.

Diversification as a complement of sugar production

Industrial production of by-products has not shown a constant, smooth development. It is estimated that at present there are about 800 factories all over the world, most of which have only started operations in the last three decades, and make use of about fifty industrial scale tested technologies. In the last decade a better integration of by-product production with sugar processing has started, in order to benefit from potential advantages in energy use, waste disposal and market penetration. The cultivation of new varieties showing higher yields of green matter for by-products' production has also been explored. The Cuban experience in by-products' development in the fields of raw materials, finishing, complexity of processes and added value can be divided in four phases of which boundaries and extensions are arbitrarily established.

The first phase covers the direct use of raw materials at low processing level.

The second phase integrates those productions using by-products as raw materials and intermediate products of sugar processing, in processes of little complexity leading to end products of special characteristics.

The third phase involves products made by chemical and biochemical changes using second-generation by-products and sugar as raw materials. Properties of products are quite different to those of raw materials from which they were prepared; technologies show medium to high complexity.

The fourth phase generates products obtained from by-products of second and third phase; they are promoters or intermediaries of other processes. Complex chemical and biochemical technologies are involved, the end products showing high added values.

These technological alternatives show that sugar-producing countries can broadly widen the horizon for sugar cane exploitation when following a diversification approach. Based on this reasoning, the main arguments used in the selection of alternatives for different by-products are as follows.

As a first rule, alternatives must be selected with high ratios of selling price to cost of intermediates or by-products used as raw materials. For development of by-products cane varieties should have high fibre content and short development time up to maximum sugar content for fermentation technologies. Whenever conditions allow, manufacture of by-products should derive from integral processes of energy balance and technology. For example the poorest juices of the milling station and the vacuum filter filtrate could be used for fermentation processes, and A and B molasses for cattle feeding.

Closed processing cycles should be adopted in order to make use of most wastes, changing them into useful products while recovering for recycling, most of the water, and hence decreasing the quantity of fresh water used and avoiding pollution. When considering the efficient use of energy in sugar processing, two approaches become evident: co-generation, and efficient use of steam; the latter is more significant when surplus bagasse is required. Benefits of co-generation described before, is the result of efficient steam generation due to higher pressures and temperatures, increasing the availability of thermal energy conversion into mechanical and resulting in a decrease of the specific steam rate index, that is, Kg of steam per kWh.

Premises in alternative selection

Selection of those showing attractive economical results

Integral layouts of involved technologies

Efficient use of energy

Flexible economy of scale

Priority to animal feeding

Non pollution of the environment

Considering alternatives for animal feeding, it is important to have installations showing flexible scale economy; maximum available raw materials in the region must be used in order to reduce handling and transportation costs. These materials can change throughout the year, depending on market conditions, but must fulfil required changes in animal diets. The situation is different with other processes having bigger scale economies requiring more complex and capital intensive technologies, such as pulp and paper, bagasse boards, amino acids, citric acid, just to mention a few (**Table 1.**). The example for Cuba is given in **Table 2.**

By-products manufacture generates wastes, which may increase pollution levels. This can be controlled by adequate use and reuse of process water in addition to the application of the necessary treatments.

In slightly over three decades, the sugar cane by-products production capacity has doubled, involving some 70 factories and nearly 300 facilities, most of them using local technology. Cuba has one of the largest numbers of technologies for manufacture of by-products, as well as the ability to generate new knowledge in this field, which enables her to further develop the product on of new derivatives.

Table 1. Present status of by-product technology development

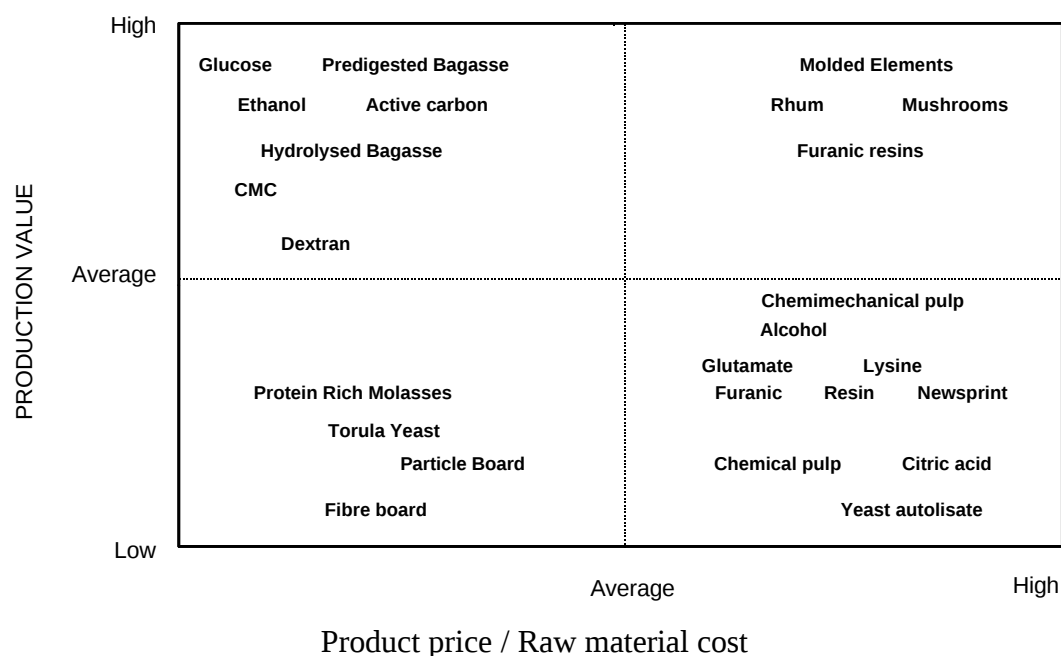
By-Products and Products	Commercial Production	Plant under Construction	Pilot Plant Scale	Laboratory Scale
Bagasse Bagacillo Pith	Pulp & paper, particle board, fibre board, cardboard, furfural, microcrystalline cellulose, hydrolysed bagasse, pre-digested pith, molasses - urea - pith, furfural cement, compost	Furfural, furfuryl alcohol, furanic resins	CMC, bagasse moulded boxes, activated carbon, nitrofurazone, nitro furan thermal insulation foam, Anticorrosive resins.	Furanic pesticides.
Final molasses 'B' molasses	Alcohol, rum, fodder yeast, yeast for human consumption, baker's yeast, yeast autolysate, high--protein molasses, alpha-amylase, azotobacter, rhizobium, CO ₂	Biopesticides, hydrolysed yeast.	Gibberellins, xanthan, protein concentrate, glucomannans, Betaglucons, Beauveria bassiana, Paecilomyces, Trichoderma, Azospirillum, absolute alcohol, clinical dextran, lactic inoculant.	Cytokinin, phytohormone
Crop residues	Animal feed, edible mushrooms compost.	Mushroom plant	Silage	Mushrooms
Filter cake	Compost, animal feed, waxes.		Pharmaceutical wax extract, phytosterols.	
Sugar	Dextran, ferridextran, glucose, sorbitol.			Jasmonic acid, indoleacetic acid
Wastes & effluents	Ferti-irrigation, biogas, animal feed.	Biogas	Biogas	
Ashes	Fertilisers.			

Table 2: Installed capacities for the production of sugar cane by-products in Cuba

Plants	Number of Plants	Installed Capacity	Facilities	Number of Facilities	Installed Capacity
Alcohol distillery	16	1 800 Mhly ⁻¹	Edible mushrooms	10	200 ty ⁻¹
CO ₂	3	18 td ⁻¹	Molasses-urea	79	600 M ty ⁻¹
Rum distilleries	11	1,2 M boxes y ⁻¹	Molasses-urea-pith	36	400 M ty ⁻¹
Fodder yeast	11	110 M ty ⁻¹	Pre-digested pith	71	350 M ty ⁻¹
Yeast for human	1	8 M ty ⁻¹	Hydrolysed bagasse	1	5 M ty ⁻¹
Particle board	5	180 M m ³ y ⁻¹	Predical	11	70 M ty ⁻¹
Fibre board	2	23 M m ³ y ⁻¹	High-protein molasses	11	450 M ty ⁻¹
Paper	5	140 M m ³ y ⁻¹	Garamber	11	100 M ty ⁻¹
Furfural	1	1 M ty ⁻¹	Pajumel	8	60 M ty ⁻¹
Dextran	1	400 ty ⁻¹			
Glucose	2				
Sorbitol	1				
Saccharomyces yeast	10	300 ty ⁻¹			
Wax	2	50 ty ⁻¹			
Alpha-amylase	5				

Development of by-products offers different alternatives from which those better suited for local conditions; available markets and financial conditions should be selected (**Figure 4**).

Figure 4 Economic Indices of Selected by-products



Enterprise leaders in industry must approach diversification as a complement of sugar production, improving the exploitation of sugar cane and contributing in this way to the sustainability of sugar economy.

LE CIRAD À LA RÉUNION : PARTENARIAT, PROGRAMMATION ET RÉSULTATS

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RESUMÉ

Avec un effectif de plus de 180 personnes dont 65 cadres et techniciens et un dispositif expérimental important mais qui demande à être encore mieux structuré, le CIRAD Réunion joue un rôle important dans le développement agricole de l'île. Au niveau des recherches, le dispositif appartient à l'ensemble du réseau CIRAD, métropolitain et international. Compte-tenu du contexte dans lequel s'inscrivent les activités du CIRAD à la Réunion, le dispositif scientifique devrait être renforcé de façon à constituer des équipes de recherche suffisamment forte pour pouvoir conduire en milieu tropical des travaux de recherche de haut niveau en parfaite complémentarité avec la programmation scientifique de l'ensemble du CIRAD. Les orientations fortes du CIRAD Réunion pourront être regroupées sous le concept de " Pôle de compétence ". Sans être limitées, les orientations déjà prises sont dans le domaine de la défense des cultures, de l'environnement, de l'agro-alimentaire et de la canne à sucre. Le renforcement du dispositif doit nécessairement prendre en compte les données de l'océan Indien et être le moteur d'une réelle coopération en partenariat avec les pays de la région. Ainsi, les opérations de recherche en partenariat sont à développer. L'accord-cadre établi entre le CIRAD et le MSIRI en décembre 1996, par exemple, devrait permettre de développer cette coopération.

Mots clés : Recherche agricole ; partenariat ; coopération régionale ; Ile de la Réunion ; Océan indien.

INTRODUCTION

La présence à la Réunion des anciens instituts de recherche d'agronomie tropicale (IRAT, IRFA, CEEMAT etc.) dont la fusion en 1984 a permis la création du CIRAD, remonte au début des années soixante. Le CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement), dont le siège est à Paris, possède ses principales installations à Montpellier et dans les DOM. Il œuvre en coopération dans une cinquantaine de pays étrangers.

À la Réunion, les activités du CIRAD s'inscrivent dans le cadre d'un fort partenariat avec le Conseil Régional et le Conseil Général, matérialisé par une convention tripartite pluriannuelle. A cette convention cadre viennent s'ajouter des conventions particulières correspondant aux différents besoins identifiés conjointement avec les collectivités locales, les organismes professionnels et la Direction de l'Agriculture et de la Forêt. Ce partenariat nécessite de fortes relations avec toutes les organisations professionnelles agricoles de façon à encore mieux adapter les orientations des recherches aux besoins du développement.

Le CIRAD doit en permanence répondre aux impératifs de la recherche scientifique (augmenter le niveau des connaissances scientifiques) et répondre aux problèmes du développement (obligation de résultats bénéficiant aux utilisateurs). Un Comité Tripartite composé des partenaires (élus et administratifs) et des représentants de l'état (Préfecture, Direction de l'Agriculture et de la Forêt, Délégué Régional à la Recherche et à la Technologie) se réunit régulièrement, en principe deux fois par an. Au cours de ces réunions sont présentés les programmes du CIRAD, les coûts, les financements, le déroulement des travaux et les résultats.

LES MECANISMES DE LA PROGRAMMATION

Pour répondre aux impératifs scientifiques et du développement, il est très important de concevoir une programmation qui doit permettre de concilier les demandes des différentes parties. En effet, la programmation du CIRAD Réunion doit s'inscrire dans le cadre de la programmation du CIRAD en général de façon à pouvoir bénéficier d'une organisation cohérente et des appuis scientifiques de l'ensemble du dispositif CIRAD.

D'autre part, localement le CIRAD a la nécessité d'identifier puis de traduire en problématique de recherche, dans le domaine de ses compétences, les demandes des différentes filières de productions agricoles. Pour ces raisons, un dialogue permanent est à entretenir à la fois avec les différents acteurs scientifiques et les organisations professionnelles de façon à pouvoir actualiser annuellement la programmation. À cet effet, chaque année, un comité technique est réuni par filière, au sein duquel sont présentés les acquis de l'année écoulée et les orientations programmées pour l'année à venir. La programmation est alors soit approuvée en l'état, soit infléchi, en fonction des remarques et observations formulées au cours du comité. L'efficacité de cette consultation est d'autant plus grande que la filière est organisée et que les différents acteurs s'impliquent, dans les aspects techniques, à quelque niveau que ce soit. Une fois approuvée en comités techniques et par les instances scientifiques du CIRAD, le document de programmation actualisé est présenté en Comité Tripartite. Ce document a une valeur contractuelle, il est annexé à la convention tripartite. A cette programmation scientifique correspond la programmation budgétaire établie pour chaque opération avec les sources de financement correspondantes.

LES PROGRAMMES DE RECHERCHE

En 1994, une étude prospective menée en collaboration avec l'Université et le Conseil Economique et Social de la Région RÉUNION a permis d'établir, sur des bases raisonnées, les grands enjeux pour la recherche agronomique à la RÉUNION dans les dix années à venir (Chastel JM et Griffon M 1994). Ils sont résumés ainsi :

- Conforter la canne à sucre
- Améliorer la compétitivité de l'agriculture
- Intégrer le petit paysannat
- Valoriser et protéger les milieux physiques et naturels
- Promouvoir l'innovation dans l'agro-alimentaire.

Cette réflexion a contribué à établir une programmation beaucoup plus précise, centrée autour des filières de production ou dispositif suivant :

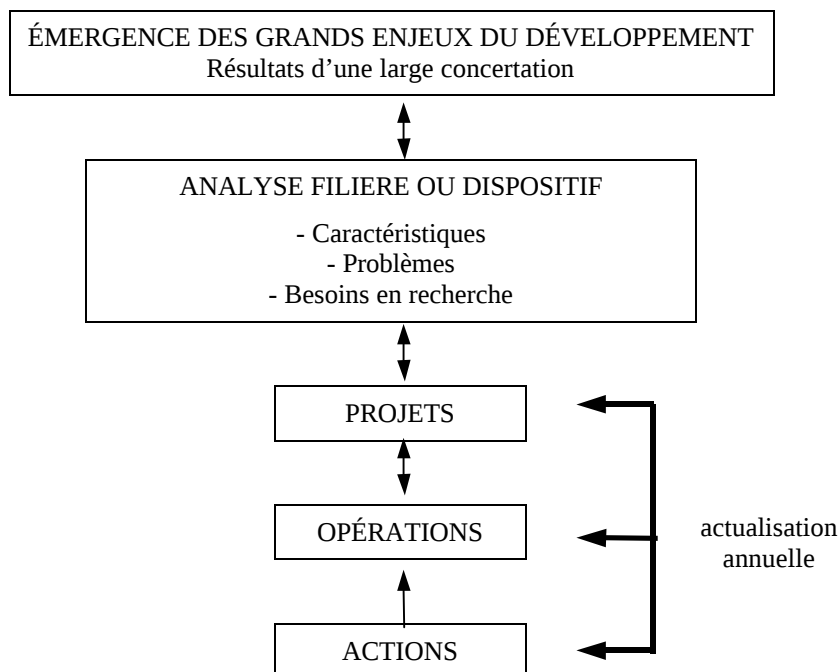
- Canne à sucre
- Maraîchage
- Plantes aromatiques
- Fruits
- Agriculture des Hauts
- Elevage
- Maïs
- Bois et forêt.

A l'intérieur de chaque filière, les activités de recherche sont organisées autour des niveaux d'objectifs suivants :

Le projet est la traduction en terme de recherche d'un ou plusieurs problèmes identifiés par les professionnels et les scientifiques. Généralement, une équipe pluridisciplinaire est nécessaire pour mettre au point les solutions qui seront mises à la disposition des utilisateurs. Pour cette raison, un projet est généralement composé de plusieurs opérations. Le projet peut être limité à une seule filière (projet vertical) ou bien commun à plusieurs filières (projet transversal).

L'opération correspond à l'activité confiée à un chercheur. Elle est, dans la plupart des cas, monodisciplinaire. Les résultats obtenus, grâce à leur fiabilité scientifique, contribuent à apporter une réponse aux problèmes que doit résoudre le projet. L'opération composée des actions de recherche fait l'objet d'une évaluation annuelle.

Schéma représentant l'élaboration de la programmation des recherches CIRAD-REUNION



L'EXEMPLE DU DISPOSITIF DE RECHERCHE SUR LA CANNE À SUCRE

Les activités de ce dispositif font partie, dans leur totalité, de la programmation Canne à sucre que le CIRAD conduit dans le monde. Ainsi, elles peuvent bénéficier de l'ensemble du réseau et y apporter leur contribution.

À la Réunion, les recherches sur la canne à sucre sont conduites par deux institutions distinctes mais complémentaires : le CERF et le CIRAD.

En 1997, pour la canne, le CIRAD met en œuvre cinq projets :

- Mise en valeur des ressources génétiques de la canne à sucre
- Elaboration d'itinéraire technique (Modèle de fonctionnement biophysique et outil de diagnostic)
- Inventaire des ennemis des cultures et protection des plantes
- Gestion des espaces et des ressources naturelles

Le CERF met en œuvre deux projets :

- Création variétale
- Appui technologique à la filière Canne.

Pour ce qui concerne le CIRAD, le tableau ci-joint met en évidence la répartition des activités de recherches par projets et opérations.

Chaque opération fait l'objet d'une fiche actualisée annuellement qui comprend :

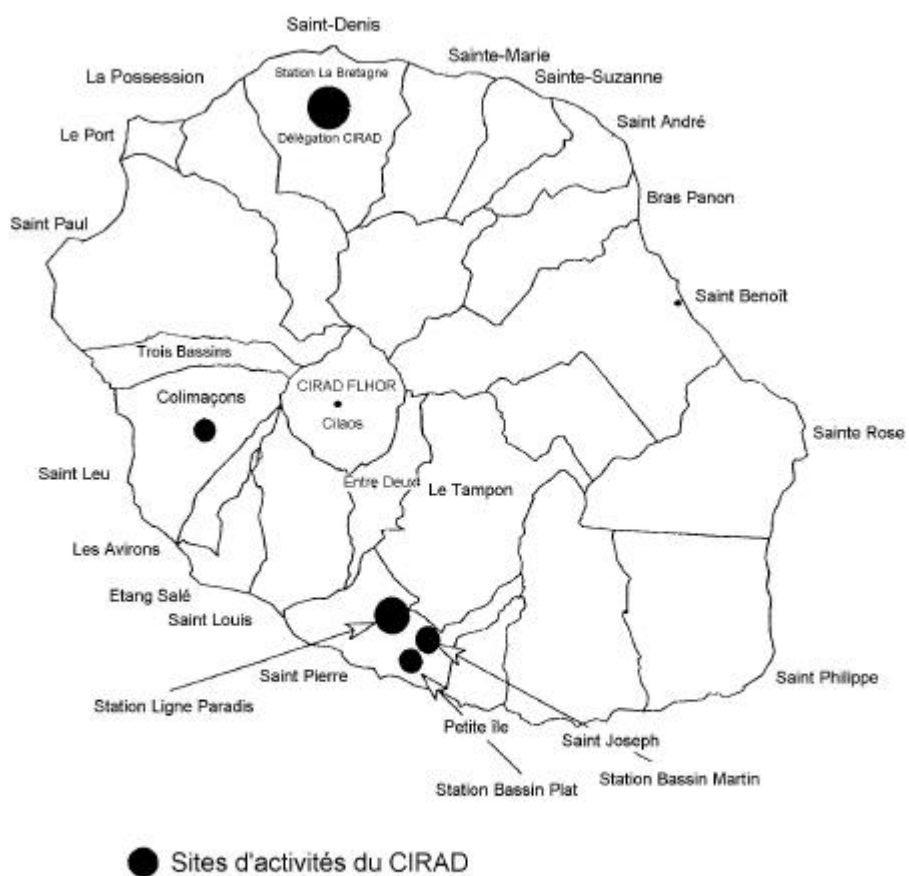
L'identification de l'opération
 Les objectifs
 Les actions prévues
 L'avancement des travaux durant l'année écoulée
 La progression attendue durant l'année à venir
 La liste des partenaires du CIRAD.

Projets et Opérations pour la Canne à sucre en 1998
Mise en valeur des ressources génétiques
Analyse génétique de la résistance à la rouille et à l'échaudure des feuilles
Analyse génétique de la résistance à la rouille et à l'échaudure des feuilles : Contribution à la Phytopathologie
Appui méthodologique à l'amélioration variétale
Appui de la Phytopathologie à l'amélioration variétale
Elaboration d'itinéraires techniques
Appui technico-économique aux groupements de planteurs et aux organismes de travaux
Gestion des matériels et planification des services
Amélioration des systèmes de production
Amélioration des systèmes de production irriguée IRRICANNE
Modèles de fonctionnement biophysique et outils de diagnostic
Modélisation de la croissance
Modélisation du rationnement hydrique de la canne à sucre et méthodologie de régionalisation des modèles bioclimatiques
Mise au point d'une méthodologie originale de la mesure du profil d'humidité du sol à partir de l'optimisation de la méthode réflectométrique
Inventaire des ennemis des cultures et protection des plantes
Surveillance des maladies
Lutte intégrée contre les ravageurs (ver blanc - borer)
Gestion des espaces et des ressources naturelles
Traitement et épuration des déchets fermentescibles par l'agriculture
Service Météo Agricole du CIRAD

LE DISPOSITIF EXPERIMENTAL

Pour mettre en œuvre les opérations de recherche, le CIRAD utilise soit les stations expérimentales, soit les réseaux d'expérimentation chez les agriculteurs et éleveurs. Les stations expérimentales du CIRAD sont dispersées dans l'île, comme le met en évidence la carte ci-jointe. Ces stations sont d'inégale importance et ont chacune leurs objectifs. Le tableau résume les fonctions de chaque site

Les Stations du CIRAD Réunion.



Fonctions des stations expérimentales

Sites d'activité	Bureaux	Laboratoires	Ateliers	Surfaces expérimentales
LA BRETAGNE	Délégation Agronomie Canne à Sucre Hauts Elevage	Analyses Entomologie Phytopathologie Canne à sucre Génétique canne Cultures in vitro	Mécanisation canne à sucre, horticulture et élevage- Entretien	Réseau d'agriculteurs
LA MARE				Expérimentation Canne à Sucre
COLIMAÇONS	Agriculture des Hauts			Cultures maraîchères Plantes de couverture
TROIS-BASSINS	Agriculture des Hauts (bureau APR)			Réseau d'agriculteurs
CILAOS				Réseau d'agriculteurs
LIGNE-PARADIS	Pôle Protection des Plantes (3P) Elevage Forêt Maïs Irrigation canne à sucre Maraîchage	3P Fruits Maïs Elevage Forêt	Entretien	Maïs Cultures maraîchères Canne à sucre Fruits Réseau d'agriculteurs
BASSIN PLAT	Fruits	Entomologie	Entretien	Fruits, pépinières, maraîchage, maïs
BASSIN MARTIN	Fruits Maraîchage			Fruits Maraîchage Réseau d'agriculteurs
SAINT-BENOIT (CFPPA)	Agriculture des hauts de l'Est			Réseau d'agriculteurs

La conduite des expérimentations pour l'exécution des opérations de recherches doit, pour une certaine partie, être menée en milieu réel, ce qui, malgré les contraintes, a pour conséquence une meilleure identification des problèmes et un transfert plus rapide des résultats auprès des utilisateurs. Un certain nombre d'expérimentations sont déjà conduites en réseau chez les agriculteurs, cette tendance sera accentuée. L'objectif du CIRAD pour les prochaines années sera de conserver en stations les essais et surfaces indispensables aux opérations de recherche qui le nécessitent et de développer de plus en plus les expérimentations chez les agriculteurs.

SYNTHÈSE DES PRINCIPAUX RÉSULTATS

Canne à sucre

Le «livre Vert » établi en mai 1996 à l'issue d'une large concertation organisée par le Conseil Général est un élément fondamental d'analyse, de diagnostic et de recommandations auquel le CIRAD, dans ses domaines de compétence, a participé. Il est nécessaire de souligner que les résultats obtenus et les

activités en cours au CIRAD, dans les domaines qui le concernent dans cette filière, sont étroitement liées aux questions soulevées au cours de la table ronde. Il est intéressant de mettre en évidence de façon très synthétique et, pour fixer les idées, les principaux acquis de la recherche obtenus ces dernières années par le CIRAD à la Réunion dans le domaine de la canne à sucre.

Les travaux menés dans le cadre de l'analyse socio-économique de cette filière ont permis d'établir un diagnostic qui conduit aux propositions suivantes :

Un changement de règles (subventions, protection des terres agricoles, forme sociale de production, etc.) est nécessaire, il doit tenir compte du caractère structurel de la crise.

Il faut réduire les instances de décision pour que les professionnels de la filière assument davantage de responsabilités afin de redonner toute sa place à l'interprofession.

La productivité du travail doit être augmentée, en intervenant à la fois au niveau des structures et au niveau des techniques.

Il serait nécessaire de faire évoluer le dispositif de soutien à la filière en le remplaçant par une aide au revenu des agriculteurs plutôt qu'une aide au prix.

Au niveau des études génétiques (CIRAD) et des créations variétales (CERF), les deux organismes travaillent en étroite collaboration :

Une connaissance approfondie des phénomènes de floraison permet au sélectionneur de mieux maîtriser les techniques d'hybridation. La mise en évidence de la présence d'un gène majeur de résistance à la rouille, associé à un marqueur moléculaire, ouvre des perspectives sérieuses en sélection par l'utilisation de marqueurs moléculaires pour obtenir des variétés de canne résistantes aux maladies, mais aussi possédant des caractères agronomiques recherchés.

Les variétés mises au point par le CERF sont systématiquement contrôlées pour leur résistance au charbon, à la rouille, à la gommose et à l'échaudure des feuilles. Les planteurs ont donc à leur disposition des variétés présentant un maximum de garanties vis-à-vis de ces maladies.

La lutte contre les insectes ravageurs de la canne a été conduite dans le but de mettre au point des techniques de lutte biologique et de lutte intégrée. Des résultats positifs ont été obtenus par la mise au point de la lutte contre le ver blanc en combinant lutte chimique (Suxon) et lutte biologique (utilisation du champignon entomopathogène *Beauveria brongniartii*). Contre le borer ponctué, les résultats déjà obtenus sur l'élevage, la dynamique des populations, la caractérisation des pertes et la biologie des parasites permettent de penser que des solutions pourront être mises au point à court et moyen terme.

Les essais fertilisation ainsi que les très nombreuses analyses faites au laboratoire du CIRAD permettent d'établir des recommandations de fumure faites aux agriculteurs avec pour conséquence un gain de production et une économie d'engrais.

Les travaux concernant l'irrigation ont eu pour résultats :

L'établissement de la cartographie des besoins en eau de la canne (déficit hydrique aléatoire à partir de 400 m d'altitude dans l'Ouest).

La création d'un réseau de stations météo automatiques coordonnés avec le réseau Météo-France utile pour l'ensemble des agriculteurs mais spécialement pour le pilotage de l'irrigation. Dans ce domaine, la Réunion est le site le plus équipé dans l'océan indien.

Une opération pilote (IRRICANNE) sur l'irrigation de la canne est conduite en partenariat avec la Chambre d'Agriculture et la SAPHIR. Les premiers résultats ont mis en évidence la possibilité de faire des économies d'eau et d'obtenir un gain de production. Ils permettent maintenant de poursuivre le transfert du concept IRRICANNE aux agriculteurs de l'Ouest.

Les travaux de mise au point d'un « modèle » de croissance de la canne à sucre, actuellement en cours, vont permettre de disposer d'un outil de diagnostic et d'aide à la décision pour les agriculteurs.

Concernant la mécanisation, des résultats ont été obtenus :

Sur l'épierrage fin, le travail du sol, la plantation mécanique, l'épandage de pesticides, la pose des tuyaux d'irrigation goutte à goutte, le chargement mécanique, le développement de la coupe mécanique « canne entière ». Les machines actuelles sont capables de travailler sur des pentes mêmes fortes (30 %).

Les travaux menés sur les techniques et l'organisation de la récolte chez les petits planteurs permettent pour des groupements livrant de 6 000 à 8 000 tonnes de facturer la coupe mécanique 40 FRF t⁻¹, le chargement mécanique 15 FRF t⁻¹, et le transfert aux points de collecte 40 FRF t⁻¹.

Maraîchage

Plantes Aromatiques

Les problèmes techniques concernant la filière 'Maraîchage' sont les suivants :

Les choix variétaux nécessitent une rupture avec les habitudes qui consistent à utiliser des variétés d'origine métropolitaine, donc pas nécessairement adaptées aux conditions écologiques de la Réunion.

Les problèmes du parasitisme et des maladies qui, malgré les progrès, restent encore un handicap certain.

Les améliorations des techniques de production qui ont pour objectifs l'amélioration de la qualité des produits et l'abaissement de leurs coûts.

Concernant la filière 'plantes aromatiques' :

Malgré les connaissances acquises et les progrès scientifiques, en l'absence d'une réelle politique de maintien et de développement de ces cultures, les résultats n'ont pas été valorisés au niveau du développement.

Les activités du CIRAD en matière de vanille consistent à venir en aide aux producteurs, en partenariat avec PROVANILLE.

La concertation permanente avec les agriculteurs a permis d'obtenir un certain nombre de résultats :

Recommandations de variétés

Des essais variétaux ont mis en évidence l'intérêt d'utiliser plus d'une quinzaine d'espèces légumières.

Des progrès ont été réalisés dans l'amélioration des variétés d'alliums (ail et oignons).

Des techniques de multiplication du haricot rouge et de la pomme de terre pour la production de semences saines ont été mises au point.

Lutte contre les maladies et adversités

Plusieurs activités dans ce domaine sont en cours. Cependant, on peut déjà souligner que de meilleures connaissances sur les insectes parasites, sur les maladies bactériennes et à virus ont permis d'établir une méthode de lutte qui doit encore être améliorée, notamment avec les méthodes de lutte intégrée (travaux en cours).

L'amélioration des techniques de production a porté sur la mise au point d'un référentiel technique original et unique sur la culture du géranium, la mise au point de la culture de l'asperge et de l'endive dans les conditions de la Réunion, l'amélioration des techniques de production sur tomate, pomme de terre, oignon (implication du CIRAD dans la programmation et la gestion technique de l'ARMEFLHOR à ses débuts).

Concernant les rendements de vanille, ils sont passés de 0.5 kg/liane en système traditionnel (source PROVANILLE) à plus de 2 kg/liane sous ombrière avec une teneur en vanilline doublée par rapport au système traditionnel 4 g/kg de gousses préparées.

Fruits

La production de fruits continue d'être une importante source de diversification des cultures. En vingt ans (1976-1996), la surface totale estimée plantée en cultures fruitières est passée de 500 ha à 2244 ha et dans le même temps, la consommation par habitant et par an passait de 40 kg à 80 kg. Les résultats du CIRAD ont contribué à ce développement.

Les fruitiers tempérés

Les essais variétaux sur fraisiers, conduits en association avec le CIREF (Centre Interrégional de Recherches et d'Expérimentation de la Fraise), permettent de faire des recommandations variétales en constante évolution. La mise au point d'itinéraires techniques : date de plantation, densité, herbicides sélectifs, mise au point d'engrais spécial fraisiers, pilotage du goutte à goutte, paillage plastique, culture sous abris, ont permis l'élaboration de fiches techniques, pour conseil aux producteurs. Ces techniques continuent d'être adaptées.

Le CIRAD a procédé à l'introduction de Métropole de nombreuses variétés de pêchers à faibles besoins en froid *Flordabelle* et *Flordared*. Ces variétés, appréciées par les agriculteurs, ont permis l'installation de vergers «d'altitude». D'autres variétés, environ une centaine, en provenance de Floride et d'Afrique du Sud, ont été installées dans le cirque de Cilaos. Environ dix variétés ont été retenues pour plantation.

Concernant la production de raisins (cuve et table), l'introduction de nombreux cépages et les essais relatifs aux itinéraires techniques ont permis, pour les raisins de cuve, l'établissement de nouvelles plantations en cépages nobles (*Chenin*, *Cot*, *Pinot*) en remplacement progressif de l'Isabelle, et concernant le raisin de table, les cépages *Alphonse Lavallée*, *Danlas*, *Cardinal*, *Muscat de Hambourg* et d'*Alexandrie*, ont remplacé les *Ribol*, *Lival*, *Delhro*. En 1996, les premiers résultats sur raisins de table montrent qu'il est possible d'obtenir deux récoltes par an.

Les fruitiers tropicaux

Les techniques de cultures intensives de bananiers ont été développées avec des résultats positifs. Cependant, une organisation de la filière est nécessaire.

La production d'ananas est intéressante et répond à un besoin à condition de s'orienter vers l'intensification et la qualité du produit. Les études sur le cycle de floraison naturelle, suivi par des essais de traitements d'induction florale (TIF) au carbure de calcium ont permis d'obtenir les premiers résultats. Les techniques culturales sur la variété Victoria : densité, itinéraire technique, TIF, ont mis en évidence l'intérêt d'une plantation à densité élevée, environ 86 000 plants ha⁻¹. La technicité de la culture augmentant, les travaux se sont orientés à compter de 1991 sur l'irrigation localisée (circo-jet, goutte à goutte) et l'élaboration de fiches techniques, la mise en place d'un logiciel de prévision de la date de récolte en fonction de la période, l'altitude, la densité, les problèmes liés aux taches noires abordés en 1997.

Il y a environ 30 ans, les contraintes sanitaires étaient telles que la production d'agrumes était en régression avec des vergers dépérissant. Le *greening*, le chancre citrique ou la *tristeza* avaient déjà été identifiés à la Réunion. Les connaissances sur ces maladies de dégénérescence et sur leur épidémiologie étaient très partielles. Aucune stratégie de lutte performante n'avait pu être définie. Les

études menées au CIRAD ont permis de réduire considérablement les pertes dues à ces maladies. D'autre part, les techniques permettant de maîtriser les différents facteurs de production des agrumes dans les conditions réunionnaises ont été rassemblées dans un manuel de vulgarisation : « La culture des agrumes à l'île de la Réunion ». Des recommandations variétales sont faites, basées sur les résultats d'essais sur différents agrumes (clémentines, orange, citron). D'autres variétés sont en cours d'évaluation.

Environ cinquante variétés de manguiers ont été plantées sur le site de Bassin-Martin pour étudier le comportement des variétés réunionnaises les plus courantes en comparaison avec les mangues d'origines floridiennes ou d'autres origines. L'expérience acquise depuis 20 ans a permis de définir les pratiques à mettre en œuvre comme : des distances optimales de plantation, le niveau des fumures, les techniques de taille, la lutte contre maladies et adventices, permettant d'obtenir régulièrement (faible alternance) plus de 20 tonnes de fruits à l'hectare avec la variété *Earlygold*. A titre de comparaison, le chiffre de 10 tonnes hectare est souvent avancé dans les grandes régions de production au niveau mondial. Deux nouveaux cultivars prometteurs originaires des USA et d'Afrique du Sud sont actuellement en phase d'évaluation.

Le litchi est une production ancienne à la Réunion, les zones traditionnelles de culture étaient constituées d'une population monovariétale dont les arbres étaient conduits souvent comme un peuplement forestier objet de cueillette plutôt que conduite d'un verger. Les essais agronomiques mis en place dès 1980 ont permis de résoudre de nombreux problèmes (densité, fumure, multiplication végétative, etc.). Des fiches techniques sont à la disposition des agriculteurs. En 1985, la constitution d'une collection à partir des introductions d'Inde, des Seychelles, d'Australie, de l'Ile Maurice et d'une prospection locale dans des plantations a permis de rassembler plus de 45 lignées. Quatre lignées ont été retenues en 1993, pour leur qualité gustative et deux pour leur précocité en 1995 et 1996. Multipliées, elles sont en cours d'implantation pour évaluation dans les sites de production traditionnelle du litchi dans l'Est et le Sud de l'île.

Agriculture des Hauts

Dans les Hauts de l'île, le CIRAD s'efforce de participer à la construction d'un développement durable autour des activités agricoles. Les actions pluridisciplinaires sont le plus souvent conduites avec les producteurs et nos partenaires du développement. Elles visent à la promotion de l'innovation et à l'accompagnement des mutations dans les systèmes de polyculture et petit élevage des Hauts.

Sols, érosion et fertilité, eau

Les cartes des sols du CIRAD constituent aujourd'hui les outils de base incontestés pour toute étude liée à l'agriculture, l'environnement, les aménagements dans les Hauts. Certaines propositions du CIRAD, relayées par les organismes de développement, sont plus largement mises en œuvre aujourd'hui (agroforesterie avec le Calliandra, maîtrise chimique des adventices et abandon du sarclage, recul du travail du sol, fertilisation chimique adaptée). Les techniques de couvertures vives mises au point par le CIRAD apparaissent très efficaces contre l'érosion, elles s'associent à des cultures pérennes dans le Sud de l'île (vergers, palmistes). L'embocagement avec des légumineuses fourragères (Calliandra) est également une solution efficace largement adoptée aujourd'hui par les polyculteurs-éleveurs des Hauts de l'Ouest et du Sud (affouragement des animaux, brise-vent). Le CIRAD, associé à la MVAD, assure la promotion des amendements organiques et fournit des référentiels technico-économiques (technique de compostage, analyses des produits). En collaboration avec la Région et les organismes de développement, le CIRAD propose des solutions pour une meilleure gestion de l'eau de retenues collinaires (planification et pilotage).

Elevage

La plupart des plantes fourragères actuellement exploitées dans les Hauts ont été caractérisées, évaluées, et parfois directement introduites à la Réunion par le CIRAD (kikuyu, cannes fourragères, dactyle, Chloris, lotier, trèfles, Calliandra, choux, avoine,...).

Systèmes de culture

Les recherches du CIRAD sur le géranium à la Réunion fournissent un référentiel technique original et unique parmi les pays producteurs.

Les résultats obtenus sur les solanées (tomate, pomme de terre, aubergine), les choux, les haricots, le maïs, ont augmenté les choix possibles pour les producteurs, et enclenché une dynamique de production locale de semences (haricot, pomme de terre) en partenariat. Des systèmes innovants intensifiés sont proposés et évalués par le CIRAD, et s'inscrivent aujourd'hui dans les pratiques et les paysages agricoles : culture de goyavier-fraise, de grenadille, de palmistes dont un multipliant.

Systèmes de production, systèmes agraires

Grâce à ses travaux sur les systèmes agraires, le CIRAD fournit à ses partenaires institutionnels des diagnostics sur la diversité des situations agricoles dans les Hauts, sur les besoins, contraintes et atouts des exploitations, ainsi que sur leur devenir possible (analyse prospective). Les typologies réalisées font aujourd'hui référence auprès des partenaires du CIRAD (SUAD, APR, Collectivités) en tant qu'outils pour fonder et raisonner les politiques.

Elevage

En 1987, à la demande de la DAF et des organisations professionnelles, une équipe pluridisciplinaire de recherche a été constituée avec 2 agronomes du CIRAD et 2 zootechniciens (INRA et ITEB). Cette équipe s'est résolument orientée vers la réponse aux questions des éleveurs. Les premiers travaux ont été ciblés vers deux préoccupations de l'élevage réunionnais :

Comment résoudre le déficit fourrager hivernal ?
Comment améliorer la reproduction des troupeaux ?

Les travaux de recherche finalisée menés ont conduit à des résultats aujourd'hui reconnus et largement relayés par le développement. La reproduction des troupeaux laitiers et allaitants est suivie par l'équipe de CIRAD Elevage en collaboration avec l'EDE depuis maintenant plus de 3 ans. Cet outil très performant est le seul en France de cette qualité. Il fait l'unanimité des éleveurs.

La technique de l'ensilage en balles enrubannées a été mise au point, elle est largement diffusée auprès des éleveurs par l'union des AFP. Cette action a permis la réalisation de stocks fourragers importants et mieux maîtrisés par les éleveurs. Cette technique constitue actuellement la principale forme de stockage de fourrages.

Des techniques de gestion raisonnée des prairies ont été mises au point. La réussite de cette action s'est traduite par le transfert des méthodes à l'union des AFP qui suit désormais un nombre croissant d'exploitations en matière de gestion des prairies. A plus long terme, c'est la protection du milieu qui est pérennisée. Les travaux menés sur la fertilisation des prairies conduisent progressivement à une meilleure utilisation des engrais et à des formules plus adaptées aux différentes situations de l'île.

Les orientations actuelles du CIRAD Réunion en matière d'élevage vont vers :

Des études concernant la gestion des flux de biomasse fourragère, avec un souci de complémentarité Canne/Elevage.

La gestion des déchets d'élevage pour valoriser les matières organiques produites par les élevages et limiter ainsi la pollution.

L'alimentation des bovins laitiers en recherchant une meilleure adéquation entre les besoins des animaux, la fourniture des fourrages et la complémentation en aliments concentrés.

L'étude des facteurs de risques de l'infertilité des troupeaux laitiers à travers un suivi écopathologique en exploitation.

L'élevage bovin à la Réunion est en plein essor et le CIRAD participe, en concertation avec tous les partenaires du développement, à son développement dans le respect de l'environnement et de la durabilité des exploitations.

Maïs

À la Réunion, la culture du maïs reste encore essentiellement traditionnelle et peu intensifiée. L'intensification de la culture peut toutefois être envisagée dans différentes situations de l'agriculture réunionnaise. Pour les agriculteurs en zone canne (en dessous de 700-800 m), planteurs au départ pour la plupart et dont certains diversifient leur activité vers l'élevage engraisseur, la culture du maïs est possible en rotation avec la canne (utilisation après arrachage des vieilles repousses) et bénéficie directement du matériel et des investissements pour cette dernière (irrigation notamment). La résistance aux viroses est le critère majeur de sélection pour cette cible qui bénéficie donc directement des résultats et des variétés issues du programme international sur les viroses mené par le CIRAD à la Réunion.

Les agriculteurs des Hauts de l'Ouest et du Sud (au-dessus de 700-800 m), très souvent maraîchers au départ, ont diversifié leur activité vers l'élevage bovin ou en ont fait leur métier principal. Dans ces zones, les maladies à champignons (rouille et helminthosporiose) et des températures relativement fraîches pendant la saison culturale rendent impérative l'utilisation de cultivars résistants et de cycle assez court. La nécessité de stocker des réserves de fourrage pour pallier le déficit de la saison fraîche (diminution de la production des pâtures) mais également pour la saison chaude (surabondance d'herbe difficilement récoltable en raison de l'excès d'humidité) offre un débouché très intéressant au maïs stocké en ensilage.

Les résultats obtenus peuvent être résumés ainsi :

Les travaux menés conduisent à la sauvegarde du patrimoine génétique des Mascareignes par la prospection des populations pays et leur brassage sous forme de composite. Un itinéraire technique de la culture a été mis au point dans les principales situations (fertilisation, besoins en irrigation, pratiques culturales, traitements pesticides) débouchant sur des conseils aux agriculteurs. La création de variétés résistantes aux viroses est effective : six variétés à pollinisation ouverte à résistance quasi-totale au *Maize Streak Virus* (MSV) ont déjà été créées et diffusées en Afrique de l'Ouest ; d'autres cultivars vont sortir prochainement, certains pouvant remplacer l'hybride précoce IRAT 143 et la variété Révolution qui sont déjà produits et commercialisés localement pour la culture traditionnelle ; cette dernière fait également l'objet d'une diffusion à Mayotte et aux Comores. La culture intensive du maïs pour la production d'ensilage est préconisée : 30 ha d'essais multilocaux chez les éleveurs ont permis le choix de 2 hybrides tropicaux originaires d'Afrique Australe (1.5 t de semences vendues par l'U.A.F.P. en 96-97) en attendant la production par le SRPS des nouvelles formules hybrides plus adaptées du CIRAD. Les travaux qui sont conduits en recherche sur le maïs ont également permis la mise au point de techniques expérimentales originales, d'accroître les connaissances scientifiques et la formation de nombreux techniciens et chercheurs dont 7 thèses déjà soutenues et 2 autres en préparation. Ces résultats contribuent au rayonnement scientifique international de la Réunion.

Forêt

L'objectif initial des travaux était de fournir une gamme d'essences forestières utilisables pour le reverdissement des basses pentes de l'Ouest. Suite à la réussite de cette opération, les investigations ont également porté sur d'autres milieux écologiques telles les zones de moyenne altitude de l'Ouest et de l'Est, ainsi que les espaces ruraux où l'agroforesterie peut occuper une place importante. Depuis 1995, les bambous font partie des espèces étudiées. D'autre part, les arrière-plages sont devenues une nouvelle zone écologique qu'il est nécessaire de protéger. Parallèlement, et devant l'extension de la gamme des végétaux et des types de milieux investigués, une partie de nos activités intervient à l'échelle des paysages (paysages littoraux, paysages ruraux, paysages forestiers). Le CIRAD intervient dans ses activités en partenariat avec l'ONF, les organismes scientifiques locaux (Conservatoire

Botanique de Mascarin, Université), avec les organismes de développement (APR, SUAD, SAFER) et d'aménagement (SAFER, DDE), avec diverses structures de formation (Lycées agricoles, CFPPA), mais également avec des structures nationales de recherche (INRA, CNRS).

Appui au développement de l'agroforesterie

Cette action a trouvé des applications immédiates, à la faveur notamment de l'émergence de mesures financières récentes (Mesures agri-environnement, projets associés au Fonds de gestion pour l'espace rural). Le programme a identifié et testé plus de vingt espèces utilisables en haies vives, certaines d'entre elles ayant été utilisées dans le cadre de l'application de ces mêmes mesures. Le *Calliandra* constitue l'espèce arbustive la plus connue parmi l'éventail des essences proposées. Outre ce choix d'espèces, des références ont été réunies dans le cadre du suivi d'un réseau de 80 haies brise-vent réparties sur l'ensemble de l'île. Ces références sont transmises aux partenaires du développement sous la forme de rapports techniques ou de fiches. Depuis 1996, une nouvelle forme d'agroforesterie est étudiée : l'intégration d'arbres au sein des pâtures. Les plantations se présentent sous la forme d'alignements périphériques ou d'arbres isolés dispersés au sein des pâtures. Les expérimentations portent sur le choix d'espèces utilisables, mais également sur l'utilisation de dispositifs de protection contre le bétail (clôtures et tubes-abris).

Végétalisation et protection des zones sèches

Cette première opération s'appuie sur un dispositif expérimental important : Forêt de l'Etang-Salé, Grand-Fond, Trois-Bassins Littoral et, jusqu'en 1996, la Pointe des Châteaux. De nombreuses espèces ont été testées (54 sur le seul site de l'Etang-Salé), les expérimentations ayant donné lieu à des rapports techniques et à des fiches. Certaines de ces essences sont aujourd'hui communément utilisées par l'ONF (rénovation de l'Etang-Salé, chantiers de réhabilitation d'arrière-plages). L'ensemble des données est regroupé dans une base de données informatisée. Avec le regain d'intérêt en faveur de zones situées immédiatement en front de mer, de nouveaux essais sont poursuivis en faveur de l'utilisation d'arbustes et d'arbrisseaux capables de résister à des embruns fréquents.

Valorisation ligneuse des zones de moyenne altitude

Le dispositif expérimental de ce second volet regroupe dix parcelles distribuées dans cinq groupes techniques de l'ONF : Saint-André (1 parcelle), Saint-Benoît (4), Saint-Philippe (2), Les Avirons (3). Un effort particulier est fourni en faveur de la valorisation possible des grands délaisés et du recours à des essences forestières endémiques. En l'absence presque totale de références préexistantes au programme sur la valorisation ligneuse de ces zones, le cheminement expérimental est plus long que pour le premier volet. Néanmoins, 8 à 10 essences peuvent d'ores et déjà être recommandées pour ces zones.

Expérimentations pour un choix de bambous

Les bambous offrent aujourd'hui de nouvelles perspectives, dans un domaine entièrement nouveau, la première expérimentation réalisée pour le criblage d'espèces de bambous à la Réunion datant de 1996 (site de Piton Saint-Leu). Le dispositif « bambous » demeure par conséquent à étendre.

PERSPECTIVES ET CONCLUSIONS

Adossé au réseau international du CIRAD, le CIRAD Réunion, avec un effectif de plus de 180 personnes dont 65 cadres et techniciens et un dispositif expérimental conséquent, joue un rôle important dans le développement agricole de l'île.

Les efforts de concertation et d'organisation menés ces dernières années, ont permis de mieux structurer l'offre de recherche du CIRAD à La Réunion. La programmation scientifique a favorisé la constitution d'équipes de recherche de taille suffisante pour conduire en milieu tropical des travaux de haut niveau complémentaires de ceux développés par le CIRAD depuis Montpellier.

Les orientations fortes du CIRAD peuvent être regroupées sous le concept de "pôle de compétence". Sans être limités, 4 domaines d'excellence sont pressentis : protection des plantes, environnement, agroalimentaire et canne à sucre. La constitution de pôle de compétence repose sur l'existence de partenariat actif tant au niveau local qu'au niveau régional.

Dans le domaine de la protection des cultures, le regroupement dans un même laboratoire, d'équipes du CIRAD, de l'Université de La Réunion, du Service de la Protection des Végétaux (SPV/DAF) et de la Fédération Départementale des Groupements de Défense des Cultures (FDGDEC) est programmé.

La mise à disposition de nouvelles infrastructures performantes et de taille adaptée permettra d'augmenter les capacités d'accueil de chercheurs, postdoctorants, doctorants et stagiaires français ou étrangers. Cela favorisera la dimension internationale des projets de recherche menés à la Réunion.

Ceux-ci doivent être résolument tournés vers des programmes d'intérêt régional à l'exemple du programme sur les mouches des fruits, mené sous l'égide de la COI, à l'île Maurice, aux Seychelles, à Madagascar, aux Comores et à la Réunion. Le développement d'un partenariat régional très actif dans le domaine de la protection des plantes est d'ailleurs l'ambition du programme régional de protection des plantes initié par le CIRAD, le SPV à la Réunion, le MSIRI et le Ministère de l'Agriculture à l'île Maurice.

Le deuxième pôle de compétence à développer est le "pôle Environnement" qui, pour le CIRAD Réunion regroupe les activités de recherche liées à la gestion des ressources naturelles, à la gestion agricole des déchets et à la gestion des espaces et de la biodiversité. Cette orientation devrait être renforcée compte tenu des enjeux présents dans les milieux écologiques fragiles des îles tropicales de l'Océan Indien. Une démarche régionale est d'ores et déjà également amorcée avec la création du RADOI (Réseau Agriculture Durable Océan Indien) auquel participent des institutions d'Afrique du Sud, des Comores, de Madagascar, du Mozambique, du Kenya et des Seychelles.

Dans le domaine de l'agroalimentaire, le CIRAD possède un savoir-faire qui pourrait être utile au développement des petites industries de transformation des produits tropicaux. Un accord cadre a été signé entre l'Université de la Réunion, la Chambre de Commerce et d'Industrie (CRITT agroalimentaire) et le CIRAD. Les équipes regroupées au sein de la Maison Régionale des Sciences et de la Technologie (MRST) représentent un potentiel de recherche et d'expertise non négligeable. Cette structure devrait donc faciliter les transferts de techniques entre l'Europe et la Réunion mais aussi au niveau régional, si l'on peut développer en partenariat des opérations de recherche originales adaptées aux besoins.

Enfin, dans le domaine de la canne à sucre, la complémentarité entre les activités du CERF et du CIRAD doit être soulignée et renforcée, de façon à créer un réel "pôle de compétence canne à sucre" à la Réunion avec toutes les retombées scientifiques et économiques qu'il pourra entraîner.

Concernant la filière canne à sucre, les relations privilégiées existantes avec l'île Maurice ne devraient que se renforcer. L'accord cadre établi entre le MSIRI et le CIRAD en décembre 1996 montre déjà tout son intérêt avec la concrétisation de la coopération dans le domaine de la génétique de la canne à sucre. Le renforcement du dispositif CIRAD à La Réunion devrait être le moteur d'une réelle coopération en partenariat avec les pays de la région.

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PRECISION AGRICULTURE - PERSPECTIVES FOR THE MAURITIAN SUGAR INDUSTRY

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ABSTRACT

Precision agriculture, (precision farming or site-specific management) is a form of mechanized agriculture that relies upon satellite-based navigational technology to map spatial variability enabling a more judicious use of inputs. It can provide the basis for improved yields and reduced costs of production. Devices such as the Global Positioning System (GPS) and yield-mapping systems, mounted on agricultural machinery, are used for data collection. Some applications of precision agriculture are described together with the characteristics of the hardware and software involved. Possible applications to sugar cane in the mauritian context are discussed with a view to demonstrating how precision agriculture can lead to lower costs and decreased environmental impact.

Keywords: Precision-agriculture, sugar industry, mapping spatial variability, Global Positioning System, Geographical Information Systems, Mauritius.

INTRODUCTION

From use of extensive land and simple tools, agriculture has progressed to intensive use of land with sophisticated farm machinery. In the recent past, the green revolution brought a tremendous change in agriculture enabling an increased capacity for crop production. Despite achievements made in fertilizer production, plant breeding, crop protection methods, etc, crop production planning has not been totally mastered. Information and engineering technologies presently available are likely to make crop production planning more precise. Crop production is achieved on an "as needed basis" allowing a cost-effective business approach through minimum inputs. This new approach is called Precision Agriculture. It represents a great leap forward for agricultural production and could lead to significant improvement in crop productivity. In the mauritian context, at a time when the sugar industry is facing critical issues such as competitiveness and the need to reduce costs of production, Precision Agriculture may be expected to contribute towards meeting these objectives.

What is precision agriculture ?

The concept of Precision Agriculture was formulated in 1986 (Fairchild 1994). It is based on the fact that variability of soil fertility, soil depth, micro-relief, microclimate, weed species, etc are natural and site-dependent and therefore have a direct bearing on crop production (Kharural et al. 1996; Earl et al. 1996; Gerhards et al. 1996). Crop production is achieved from "prescribed" inputs made on an "as needed basis" and calls upon the support of information and engineering technologies as micro-computers, geographical information systems (GIS), global positioning system (GPS) and automatic control of farm machinery. Instead of managing fields with average requirements or with general types of recommendation, fields can now be managed by variable rates of inputs that are specific to the site conditions. By this method, crop yield can be better controlled and low-yielding areas can be better managed resulting in increased productivity. It will also result in a judicious use and economy of inputs as well as being environment friendly. Extra inputs of fertilizers or biocides in non-desired areas will then be avoided thereby minimizing risks of pollution. Further aspects on the philosophy, technology and benefits of Precision Agriculture have been reviewed by (Graham and Dawe 1995) and (Toft and Dorward 1995). Precision Agriculture has been developed and applied mainly in Europe and the United States particularly in wheat, barley, corn and soybean. But its application is being extended to

other crops such as potato, cotton, sugar beet and sugar cane. Other names used in lieu of Precision Agriculture are *Precision Farming*, *Prescriptive Farming*, *Variable Rate Farming*, *Site-Specific Management*, *Soil Specific Crop Management*, *Farming by Computer*, *Farming by satellite*, *Computer-assisted Agriculture*, *Automated Agriculture*, *Farming by Foot*, *Cyberfarm*, etc.

Information and engineering aspects of precision agriculture

Precision Agriculture has been made possible because of impressive progress achieved in information and engineering technologies. These technologies are associated with the four phases of Precision Agriculture: observation, interpretation, evaluation and implementation. In the observation phase, referenced spatial variable data are collected with the help of yield-mapping systems (sensors), aerial photographs and satellite imageries together with a global positioning system (GPS). Databases are compiled within a geographical information system (GIS), essential for managing the huge amount of information. In the interpretation and evaluation phases, processes involve data querying, spatial analysis, and generation of models for soil behaviour/crop performance with appropriate software tools while control measures are also formulated. In the final phase of implementation, control is achieved with variable rate applicators/spreaders for applying inputs on an “as needed basis”. Integrating the different processes and controls involved in the four phases in a well designed Decision Support System is vital.

A typical approach for mapping yield variations in the field consists of a combine harvester or a side trailer equipped with a yield monitor sensor for measuring flow rate of crops (volume for grain and mass for crops such as potato, sugar beet and sugar cane). A GPS field guide system is mounted on top of the harvester to give correct positions in latitudes / longitudes / altitudes (or Eastings and Northings) as the harvester moves along rows. The GPS is a satellite-based navigational technology that receives signals from 24 satellites in space and computes the position (in x, y, and z) of any point on the surface of the earth. Yield variations will be recorded and shown as a map. Mapping spatial variables related to soils is achieved by grid sampling and geo-statistical methods (Franzen et al. 1996; Mohamed et al. 1996). However, other rapid and automatic methods are being explored by using mobile systems (soil chemical sensors mounted on small vehicles) to measure chemical properties of soils like organic matter, soil moisture, nitrate levels, etc (Borgelt 1992; Lui et al. 1996; Wright 1996). The GPS is a part of the system for referencing the points where measurements have been made. Weeds and other biotic factors may be mapped with the aid of aerial photographs or satellite imageries. For variable rate applications (of fertilizers, ameliorants, and biocides), the tractor is equipped with variable rate applicators or spreaders and a GPS field guide system to show the areas where variable rates need to be applied. Other applications involve digital terrain modeling (Bell et al. 1994; Verhagen et al. 1994; Haneklaus et al. 1996), and soil dynamic modeling techniques for characterization of uncertainty in soils (Mays et al. 1994), or water and chemical fluxes and crop growth (Bouma 1994). The modeling techniques provide information on soil behaviour for minimizing inputs and leaching / run-off of agrochemicals.

Other technologies like the video image analysis have been reckoned to provide capabilities for detecting patterns related to soil sampling and mapping (Beverly et al. 1995) and voice recognition systems developed for automatic recording of spatial variable data while operating a tractor / combine harvester (Dux et al. 1997). The success of Precision Agriculture will be assured if the necessary mobile sensor for mapping soils and biotic factors become commercially available, as manual sampling of these factors has proved to be costly and impractical.

The sugar industry

Precision Agriculture has already been applied in the sugar industry. In Florida, grid soil sampling techniques have been adopted to produce rate application maps for fertilizer, lime and calcium silicate slag to be used with rate controllers. Yield mapping is carried out by means of infrared photography and satellite imagery (Lockhart and Murray 1997) but a field worthy yield sensor monitoring system is not yet available. In Australia, however, the development of yield monitors has been a primary concern. Mass flow rate measurements for a prototype yield monitor has received attention (Cox et al. 1996a; Cox et al. 1996b; Cox et al. 1997). For the 1998 cane crop, three yield monitors attached to harvesters have been evaluated for their potential to map yield variations (Cox 1998). Furthermore, a workshop

was organized in June 1997 to overview the application of Precision Agriculture and its benefits to the Australian sugar industry (Bramley et al. 1997).

On the manufacturers' side (Cameco, Case IH), investigations are going on to provide the necessary facilities to cane harvesters for the operation of yield monitoring systems (Mondet, pers. comm.; Taske, pers. Comm. ; Willet, pers. comm.).

Perspectives for Mauritius

Can Precision Agriculture be applied to the sugar industry in Mauritius ? The following aspects must be taken into account to meet comprehensively this question :

- Crop mechanization,
- Spatial variability of resources,
- Reduction of costs of production and competitiveness,
- Environment protection,
- Databases and GIS, and
- Research needs.

Crop mechanization

The necessity to mechanize cultural operations, including planting and harvesting, has been recognized. This situation has stemmed from shortage of labour. Programmes of mechanization mostly on large sugar estates' land have been initiated and are on going. In this implementation process, fields and roads have been re-designed and land planed (by means of cut and fill techniques) to allow the efficient use of machines. Precision Agriculture is much easier to introduce than if there were no mechanized operations. Yield monitoring and variable rate applications for fertilizers and biocides can be tested and adopted. The investment in Precision Agriculture will therefore involve only additional costs of equipment like yield sensors, GPS field guide systems, and variable rate applicators. These costs have been calculated to be minimal compared to heavy investment in machines (Cox DRV 1997).

Spatial variability of resources

Spatial variability of soil / climate/ biotic parameters may be important for realizing variable rate applications being given the size of farms. This is so because the geological nature of parent materials has given rise to considerable variations of landform over small areas. A clear example is the hummocky and chaotic topography in the north, east and west of the island. For this type of landform, soil depth is very limited on hummocks while in the troughs soil is deeper. Evidently, the soil fertility, water availability, organic matter content, etc will also vary according to soil depth. On the other hand, microclimates are dominant features and favour variable leaching conditions or weed growth. These variable parameters and seasonal variations will certainly influence yield potential. The extent of influence has to be determined. It has been observed that the greater the spatial variability of environmental parameters the greater is the opportunity for cost-effectiveness of Precision Agriculture (Forcella 1992).

Reduction of costs of production and competitiveness

Cost-benefit analysis has been conducted for crops and variable rate applications. Net benefits have been demonstrated in certain cases and not in others (Earl et al. 1996; Hammond 1992; Snyder et al. 1996). Furthermore the higher the crop value and the number of controlled inputs, the greater the possibility for benefits to be derived from Precision Agriculture (Swinton and Ahmad 1996). In the sugar industry, results of cost-benefit analysis are not available yet. However, the benefits expected have been reviewed and appraised (Bramley et al. 1997). In Mauritius, as the primary aim of the sugar industry is to be competitive and to cut down costs of production, the contribution of Precision Agriculture cannot be overlooked. It should be a part in the overall strategy to increase productivity at minimum costs.

Environment protection

The public has a concern over the excessive use of agrochemical products that could harm the environment. Though environmental pollution by agrochemicals is far from being a critical situation in Mauritius (Autrey and Ng Kee Kwong 1997), Precision Agriculture would be an appropriate management system to regulate applications of agrochemical products. It will demonstrate that over application of agrochemical products in non-desired areas can be avoided and that off-site export of the products will not take place or might be negligible and kept well below accepted tolerance values.

Databases and GIS

Data management using GIS or expert systems for Precision Agriculture is a dominant aspect of Precision Agriculture (McGrath et al.1994; Usery et al. 1995). Valuable spatial data on the characteristics of land, climate and crop for sugar cane fields have already been compiled (Land Index Databases) while also a highly performing GIS for the management of the sugar cane land (GISCANE) is also operational at the Mauritius Sugar Industry Research Institute (Anon 1992; Jhoty 1995). For the initiation of Precision Agriculture this represents an important asset. Only additional data related to Precision Agriculture would need to be compiled.

Research Needs

Research on Precision Agriculture is progressing in many countries aiming at making it a routine practice. In the mauritian context, research should concentrate on yield variations, spatial variability, variable rate applications supported by economic analysis. The best approach would be to constitute a working group involving resource persons of different disciplines to look into the various factors and issues that would influence Precision Agriculture. As the research progresses it will then be possible to provide answers to such questions as:

- Can spatial variability be managed to allow variable rate applications?
- What are the interacting factors that affect yield most on small areas?
- How precise variable rate inputs can be applied to the desired area?
- As a result of the effective management of variable rate inputs, can there be reduction of costs of inputs?
- What are the costs to be involved and how cost-effective can Precision Agriculture be?
- Will it involve other changes in management of fields?
- Will this method of farming be possible for the small planters' community?
- In spite of success, what will be its rate of acceptance by the planting community?

CONCLUSION

Precision Agriculture should be a part of the action plan aiming at making the industry more competitive, productive and compliant with environmental regulations. Its associated technology is being continuously improved and as agricultural machines will soon be equipped with the appropriate tools it will be possible to assess the real potential of Precision Agriculture. On-going programmes of crop mechanization and the availability of agricultural information database management systems favour its introduction. Furthermore, Precision Agriculture offers the possibility for a real multidisciplinary approach towards increasing productivity and should be evaluated without delay.

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THE SCOPE OF INFORMATION TECHNOLOGY APPLICATIONS IN AGRICULTURAL EXTENSION IN MAURITIUS

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ABSTRACT

A survey was carried out to identify the information needs of extension in Mauritius and the perception of the extension officers of the use of IT in their work. The possibilities and potential benefits of providing information required by agricultural extension through IT were also determined. Reaching 97% of all extension officers involved with sugarcane and other crops and livestock, the survey revealed that a wide range of information (on crop and animal husbandry practices, results of research, new technologies developed locally, market, individual farmer profiles) can be stored on a computer, and updated when necessary. Moreover, IT can provide information required for decision-making and planning locally improve the information flow within the agricultural community; information required for their work with increased efficiency of the agricultural extension. Extension officers generally possess basic skills required to use a computer and are keen to make use of IT in their work. However, the introduction of IT in extension will largely depend on the commitments of the institutions involved to provide further training and the necessary infrastructure.

Keywords: information technology, extension, technology transfer, Mauritius

INTRODUCTION

With the integration of its economy in the global trade systems, Mauritius has to improve the productivity and competitiveness of its economic and trade sectors. The agricultural sector is faced with the challenge of its modernisation. It lags behind other economic sectors with the gradual erosion of its resource-base in favour of new sectors like industry, tourism and services, and the advent of a harsher and more competitive external trade environment.

Agriculture has thus to develop through technology improvements and increased efficiency at all levels. (MEPD 1993). However this transition from a resource-based to a technology-based system of agriculture places greater responsibility on agricultural extension, which acts as a vital conduit of new agricultural information and technologies to farmers, as well as, feedback to researchers and policy-makers of farmer's problems, needs and concerns (Kleps and Absher 1997). Generally, extension aims to bring up-to-date and reliable information about farming to those who need it, in a way that is understandable as well as useful to them (Jacobsen 1987). Therefore, an efficient extension service which provides the appropriate information at the right time to farmers, will no doubt, help to increase the productivity of farmers in Mauritius. However, extension officers must understand farming as a whole, be able to identify appropriate options and effectively draw on different sources of information or assistance, to play their role fully.

The development of computers and improvements in telecommunications offer many new opportunities to obtain technical and economic information quickly and to use it effectively for decision-making. Furthermore, in formulating a National Information Technology Strategy Plan, the government is aiming to turn Mauritius into a nation where information technology (IT) will be fully exploited to improve business competitiveness, quality of life, and to generally encourage IT diffusion at the national level. Thus, much effort is also being placed on encouraging the adoption of new technology in agriculture. Information and communication technologies can help this modernising process by improving information flow among the concerned parties. However, to date, the agricultural sector has been slow to adopt the use of information technology despite its potential to improve efficiency of planning and decision making (Bheenick 1998).

A study has been carried out, at the end of 1997, to examine the potential of information technology applications in agricultural extension. The study was based on a survey of extension officers in Mauritius, to determine their perception of how extension is carried out in Mauritius, which information are useful to extension and their information sources, the format in which the information is provided to farmers, the usefulness of IT in extension, the kinds of information which can be stored in IT applications and the computer skills of extension officers. The information thus gathered has then been used to determine whether IT has a role to play in the future of agricultural extension in Mauritius.

METHODOLOGY

The organisation of extension as it is carried out locally can be categorised into three fields namely crop, livestock and sugarcane. The Agricultural Research and Extension Unit (AREU) is responsible for non-sugar crop and livestock extension. Officers of the Mauritius Sugar Industry Research Institute (MSIRI) and managers of the Farmer's Service Corporation Centres around the island deal with sugarcane extension. Each of these organisation has its own objectives with respect to extension (Gya and Guness 1995; Naidu 1995; Pillay 1995; Rajkomar 1995). A list of extension officers was obtained from the AREU and the MSIRI. The FSC Centre managers, also interviewed as part of the survey since they deal with sugarcane extension, were also categorised as sugarcane extension officers. Thus, the survey involved 14 extension officers from AREU, 5 extension officers from MSIRI and 10 FSC managers representing all extension officers in office except one (96.7% of the population). Background information on extension locally was gathered through contacts with resource persons at Agricultural Research Extension Unit, Mauritius Sugar Industry Research Institute and the Farmers' Service Corporation as well as with those who had previously worked as extension officers. The survey questionnaire was tested with a group of persons who had previously worked in agricultural extension, and was finalised in the light of the feedback received. A copy of the questionnaire is available elsewhere (Brizmohun 1998). Most of the survey was carried out as personal interviews but some officers preferred to answer at their own convenience either because of a busy time schedule or because they felt more comfortable in the absence of the interviewer. In the latter case, the survey questionnaire was collected a few days later and any clarifications or unfilled items of the questionnaire were completed during the meeting. The completed questionnaires were verified and the items coded. Data analysis was carried out using the SPSS (Statistical Package for Social Scientist) software. Frequency tables were drawn for each item coded and cross-tabulations were worked out to investigate the relationship between items.

RESULTS

Profile of extension officers

Age and experience

Most (90%) of the extension officers are males and their age group varies largely. About two-thirds of extension officers are below the age of 45 years while a small percentage (3.4%) is above 50 years old. Sixty two percent of extension officers have less than 10 years experience in extension while 13.8 % of the extension officers have more than 20 years experience in extension.

Access to computers and use

Extension officers may have access to computers either at home, at office or both. Fifty percent of extension officers have access to computers at the office. However, while 80% of sugarcane extension officers have computers in the office, the majority of livestock officers (75%) have no access at all (Table 1).

Table 1 Access to computers by extension officers %

Field	Home	Office	Home & office	No access	Total
Crop	33	11	11	44	100
Livestock	25			75	100
Sugarcane		60	20	20	100
<i>Overall</i>	<i>14</i>	<i>36</i>	<i>14</i>	<i>36</i>	<i>100</i>

Eighty nine percent of extension officers having access to computers use the computer. Extension officers use the computer primarily for word processing (81), while 63 also make use of spreadsheet applications. Sugarcane extension officers also access SIRITELL (6), an information system developed by the MSIRI, through the computer.

Formal training

More than half of extension officers (59) have followed a course in information technology while 55 of extension officers are willing to follow courses in information technology (**Table 2**). Thus, about half of the extension officers (47) who have already followed courses in IT are eager to further improve their computer skills. Most of sugarcane extension officers (80) have followed a course in IT. The majority of extension officers (75) who are interested in following a course in IT are below the age of 45 years, 17 between 46-50 years and the rest (8) above 50 years.

Table 2 % of extension officers having followed or interested in following courses in IT

Field	Have followed	Willing to follow
Crop	40	70
Livestock	25	75
Sugarcane	80	40
<i>Overall</i>	<i>59</i>	<i>55</i>

User computer skills

About two thirds of the extension officers have the basic skills required to use a computer, i.e., they can click on and move objects on the screen. Moreover, these extension officers can enter data onto a computer to create a document and save the file onto a disk (**Table 3**).

Table 3 Computer skills acquired by extension officers

Computer Skills	Frequency %
Using the mouse to click on and drag objects on the screen	66
Copy files from a diskette to hard disk	62
Opening a file which has been saved as a Word Document	69
Typing a letter and saving the file to disk	72
Making a graph on the computer	59
Printing a document	66
Protecting a document from unauthorised access	24

Use of the internet and electronic mail

The internet and use of e-mail are relatively new to extension officers as the majority of extension officers have neither used the internet (86) nor e-mail (68). Three quarters of those extension officers

using the Internet have access to computers at office, while one third of extension officers using e-mail have access to computers only at home.

The practice of extension: interaction with farmers

Extension officers interact with farmers in several ways, namely through individual meetings; group meetings including workshops, seminars and training sessions; mass media (radio talks) and through publications. In all three fields of extension, individual meetings constitute the most important method of extension. Extension officers carry out individual meetings 65 of the time while, on average, group meetings are carried out 26 of the time.

Individual Meetings

The frequency of visits of extension officers to farmers varies depending on the field of extension (Figure 1). The majority of crop extension officers (90) carry out visits fortnightly while three quarters of livestock extension officers visit farmers at intervals longer than monthly. In sugarcane extension, the frequency of visits by extension officers varied with 47 carrying out visits fortnightly and 40 visiting sugarcane planters at monthly or longer than monthly intervals.

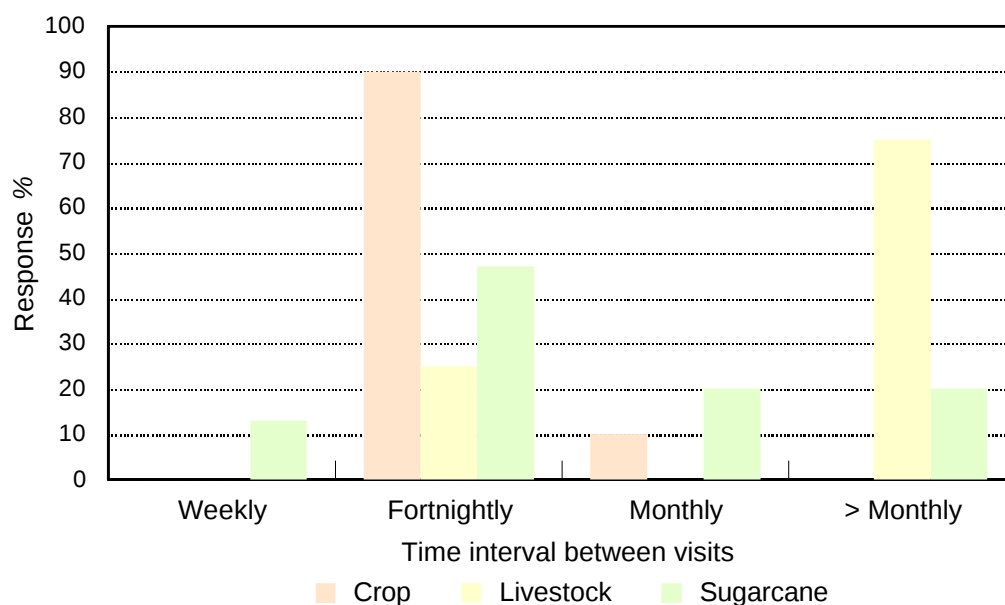
Group Meetings

The frequency of group meetings and the size of the groups vary depending on the field of extension. Crop extension officers tend to organise group meetings either fortnightly (40) or on a monthly / longer than monthly basis (Figure 2). Sixty percent of the time, the group size comprises 5-10 farmers or else it is a larger group. Half of the livestock extension officers hold group meetings fortnightly while the other half organise meetings at monthly or longer than monthly intervals. The average size of the group is often (75) between 5-10. Sugarcane extension officers generally organise group meetings monthly (53) and the number of sugarcane planters attending these group meetings is almost always (93) greater than 10.

Success rate of meeting farmers during visits

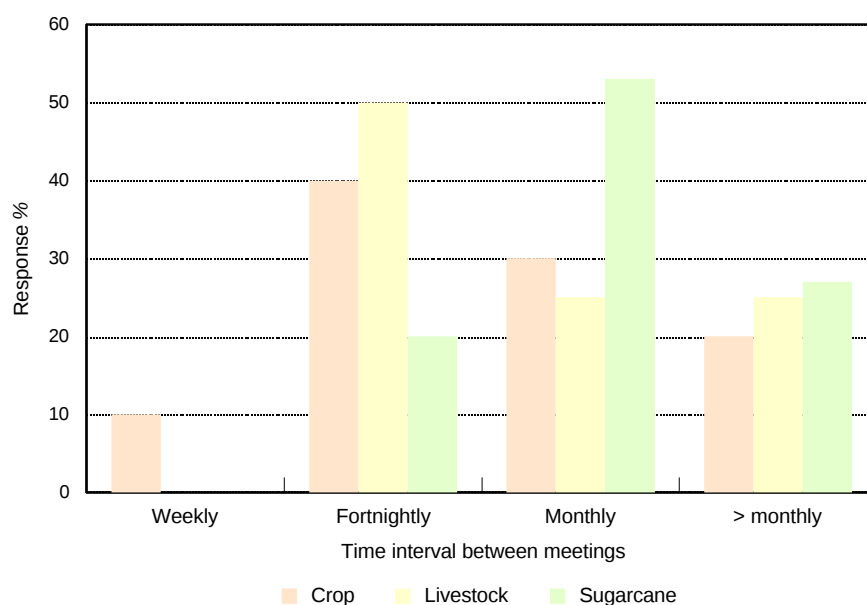
Extension officers generally manage to meet 40 - 80 of the farmers regularly. However the success rate varies among the fields of extension. In crop extension, most (80) of the extension officers are able to meet an average of 60 of farmers. Similarly, in the livestock sector, three quarters of the extension officers generally meet 60 of farmers while in sugarcane extension, 53 of extension officers meet 40-60 of the sugarcane planters.

Figure 1 Frequency of visits to farmers for individual meetings by extension officers



The primary reason (90) for not being able to meet farmers is because the latter are part-time farmers, while 56 of extension officers believe they are not able to meet farmers because of the latter's lack of interest.

Figure 2 Frequency of group meetings in extension



Farmer-initiated meetings

Meetings also take place upon the initiative of the farmers when they are faced with a problem. Farmers generally contact extension officers by visiting the latter personally at the office or else they contact extension officers by telephone or by sending letters to the extension unit. Crop growers mostly (90) visit the extension officers at the office, phone in (80) or send letters (70) to the extension department. All livestock farmers come to the office when faced with problems, alternatively they use the phone (75) or mail (50). Sugarcane planters usually phone the extension services (67) when help is required or they visit the office (60) to obtain information

Research, extension and farmer linkage

Extension is generally viewed as providing the link between applied research and the problems faced by farmers in the field. Therefore it is expected on one hand, to help in determining areas of research to solve agricultural problems locally, and on the other hand transfer the results of research to farmers. Several areas of research in each field have been determined locally as a result of extension officers being in contact with farmers and the feedback provided to researchers (Table 4). Most crop extension officers (88) state that extension has helped to guide the direction of research in pest and disease control, while the main area of research determined by extension in the livestock sector is to find solutions for the shortage of fodder. In sugarcane extension, the main area of research determined by extension has been in selecting varieties adapted to particular regions. Pest and disease problems and to a lesser extent weed management and the use of ripeners in sugarcane fields are also research issues determined by extension, following their interaction with farmers.

Table 4 Main areas of research determined by extension

Field	Area of research	Response of Extension Officer %
Crop	Pest and Disease Control	88
	Choice of varieties	12
Livestock	Problem of fodder shortage	67
	Growth monitoring	33
Sugarcane	Choice of varieties	73
	Pest and Disease Control	12
	Weed management	6
	Use of Ripeners	6

On the other hand, extension has also transferred the results of research to farmers; on new varieties of crops (60), methods of pest and disease control in crops (20) and new technology, including post harvest technology. Livestock extension has transferred research results in the area of animal nutrition (with respect to silage production and feeding of molasses) as well as demonstrated and taught farmers how to use flytraps to control flies. Sugarcane extension officers have most often disseminated information on soil amendments and fertiliser requirements of sugarcane (73) and new varieties of sugarcane released (66). Weed control and irrigation methods are among the other issues on which the results of research are transferred to farmers.

Transfer of information to farmers

Different types of information are usually provided to farmers. Advisory type of information, that is, information, which supports farmers in solving problems related to their profession, is most often (35) provided by extension officers. Information on agricultural practices, economic and market situations in agriculture (informational type) is the second most popular (24) type of information provided, while dissemination of information on the application of latest technology and, educational information, aiming to supplement and increase the professional skills of farmers are less popular (20). The majority of extension officers (93) rank personal communication as the most important format in which they provide information to farmers. The other formats used are publications (86), audiovisual means (70) and conducted tours / demonstrations (58).

Information needs of farmers (as viewed by extension officers)

The issues commonly raised by farmers give an indication of the type of information required by extension officers (Table 5). In the field of crop extension, the issues commonly raised deal with control of pest and diseases; seed availability and market information, while livestock keepers are commonly faced with the problems of lack of animals for purchase and untimely artificial insemination. Fodder unavailability is also an important issue raised by livestock keepers. In the sugarcane sector, the majority of sugarcane planters require information on weed control and fertilizer application from extension officers. Sugarcane extension officers also have to provide advice on choosing a sugarcane variety suitable for a particular region as well as solutions to the problems of water shortage.

Table 5 Classification of the issues raised by farmers

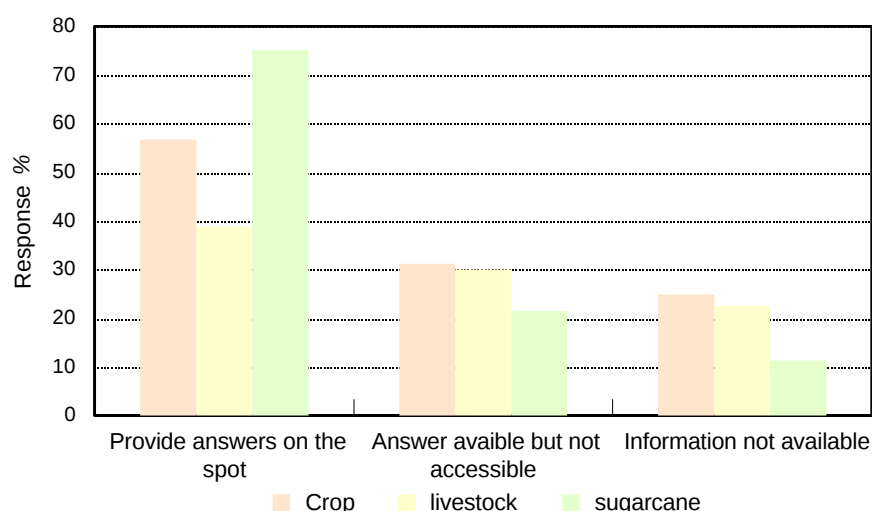
Field	Issues	Frequency %
Crop	Control of pest and diseases in crops	70
	Seed availability	60
	Market information	50
Livestock	<i>Lack of animals for purchase</i>	75
	Veterinary services / artificial insemination	75
	<i>Fodder shortage / irregular supply of feed</i>	50
Sugarcane	Weed control and fertiliser application	53
	Choice of varieties	47
	Irrigation problems	47
	Cost of production	40

Response to information needs of farmers

Generally, extension officers provide answers to queries by the farmer on the spot. However, the extent to which this is possible varies among the areas of extension. In the case of sugarcane, extension officers provide information on the spot to issues raised by sugarcane planters 70 of the time while this percentage is lower in crop (50) and livestock extension (42) (**Figure 3**).

The answers to the queries raised by farmers are sometimes available but not readily accessible. In sugarcane extension, this occurs 20 of the time while in crop and livestock extension, around 30 of the time, extension officers do not have the information at hand to provide to farmers.

However, it does occur that information required by farmers is not available when requested and research should be carried out. This occurs 10 of the time in sugarcane extension, 22 in crop extension and 25 in livestock extension.

Figure 3 Response of extension officers to information needs of farmers

Sources of latest information for extension officers

Extension officers are usually required to provide latest and up-to-date information to farmers. Ninety six percent of extension officers obtain latest information from their own reading. Other ways of accessing latest information are through official meetings with researchers (89.3) and through interactions with officers of the same grade (82.2). Information is also obtained from local extension publications (80.7) or from specialists in the division (77.8) while farmers themselves (60.7) often act as a source of information. Suppliers of inputs are not often used as a source of information while very few extension officers (21.7) presently obtain information from the Internet.

Perception of IT applications in extension by extension officers

A majority of extension officers consider information on husbandry and management practices and information on new technology as the most important broad areas in which information which can be provided to them through IT (**Table 6**). Information to be used for decision-making at farm level is ranked next in order of importance.

Table 6 Extension Officers' ranking of six broad areas, which can be provided through IT

Information on:	% Respondents		
	Very Important	Important	Least Important
Husbandry and management practices	69	21	10
New technology	69	10	21
Decision-making at the farm level	57	32	11
Reports on research findings	55	21	24
Market requirements	43	29	28
Decision-making at the national level	39	21	39

Further investigation into the perception of extension officers on the use of IT shows that they agree that IT can be used to obtain a variety of information ranging from information on crop husbandry, animal breeding, information on pests, information on land suitability to guidance information for new farmers (**Table 7**).

Table 7 Extension officers' perception of the use of IT in obtaining information

Information on:	% Respondents		
	Agree	Not Sure	Disagree
Management and crop / animal husbandry	100		
Occurrence of injurious insects	89	11	
Land suitability	89	11	
Animal improvement and breeding	86	9	5
Guidance information for new farmers	86	7	7
Governmental and statistical information	84	12	4
Marketing of fruits and vegetables	81	11	8
Research titles and topics in national research centres	77	15	8
Milk production and testing	75	25	
Rural area and production	67	29	4

Perception of sector-specific applications of IT in extension

After obtaining a general idea of the information requirements of extension officers, the latter ranked the importance of specific information that could be made available to them through IT applications such as a database and an information system.

Perceptions on a database / information system in field of crop / sugarcane

All extension officers considered a database containing such information as: name of planter; crops grown in a particular season; acreage under crop/sugarcane production; varieties of sugarcane/ crop grown; planting date; amount of fertiliser / manure applied; pest and disease encountered; chemicals used to control pest and diseases be provided to extension officers, either as essential (52) or very useful (48).

All crop and sugarcane extension officers consider the results of research in agriculture as important and useful to have on a computer. 88 of extension officers would like to have information on new technologies available on computer (**Table 8**)

Table 8 Importance of information in crop / sugarcane extension and its usefulness on an information system

Information on	% Respondents		
	Useful to have on computer	Acquired by working experience	Not required
Results of research carried out locally and abroad	100		
New technologies	88	8	4
New agricultural products available on the market	79	17	4
Prices of inputs	77	14	9
Varieties grown in particular areas	67	33	
Soil and climatic requirements	67	29	4
Cultural practices: fertilisation; irrigation; pest and disease control	61	39	
Places where inputs can be obtained	57	38	5
Land preparation and planting methods	27	73	
Expected yield in a given region	21	71	8

Information on new agricultural products, information on prices of inputs, varieties grown in particular areas, soil and climatic requirements of crops and cultural practices are important information which over half of crop and sugarcane extension officers consider important, but a large share of the extension

officers also believe that these information can be acquired with work experience. Land preparation and planting methods as well as expected yields are important but generally not considered as useful to have on a computer.

Perceptions on a database / information system in field of livestock extension

All livestock extension officers considered a database for the livestock sector be created containing information such as: name of livestock keeper; number of heads of livestock; age of animals; breed; feeding practices carried out by farmer; rearing system adopted; pest, disease and other problems encountered; monitoring of pregnancy in cattle and calving rate; and vaccination programs followed as database as either very useful (50) or essential.

Information on feeding management of livestock and results of research carried out locally are important information which all livestock extension officers find would be useful to have on an information system while 67 of them consider information on diseases affecting livestock as important and would like to have such information on a computer. However, information on housing condition of livestock, prices of inputs including feed, breeds of animal and knowledge of the sources of feeds and other inputs are often acquired through working experience(**Table 9**).

Table 9 Importance of information in livestock extension and its usefulness of an information system

Information	% Respondents		
	Useful to have on computer	Acquired by working experience	Not required
Feeding Management	100		
Results of Research carried out locally	100		
Diseases	67		33
Housing conditions	50	50	
Prices of feed and other inputs	50	50	
Breeds of animal	50	25	25
Places where feeds and other inputs are obtained	25	75	

Immediate applications of IT in extension

All extension officers recognise the use of computers in their work as a tool to store, process and retrieve information, with a range of objectives more pertinent to the field of extension and the main issues raised by farmers (**Table 10**). Thus, crop extension officers would presently use computers to access information on new technology and research findings, especially on pest and disease control. Sugarcane and livestock extension officers see the immediate applications of computers in their work as accessing a database on the individual farmers and as a means of speeding up the flow of information and communication.

Table 10 Currently envisaged potential applications of computers in the extension officer's work

Immediate applications of computers in the extension officer's work	Response %
Crops	
Store, access and retrieve information required for work	30
Information on pest and disease control	20
Comparison of yields in different areas	20
Information available on new technology and research findings can be accessed easily	20
Information on crop production can help to analyse and plan market demand and supply	10
Timely and up to date information for decision making may be obtained	10
Livestock	
Keeping records of visits carried out by extension officers	25
Data information flow between research and extension is facilitated	25
Follow up of farmer's activities	25
Sugarcane	
Data processing	53
Accessing databases of individual planters	47
Rapid method to manage information in an efficient way	40
Availability of latest information	20
Essential tool	20
Input and output of data for proper decision making	20
No need to keep bulky files	6

Importance of computer networking in extension

All extension officers believe that a computer network linking extension offices is useful. The various groups of extension officers illustrated the applications in their field of extension. Crop extension officers believe that computer networking may improve the extension process itself, for example, through more rapid and efficient information flow among researchers and farmers, eliminating a lot of paper work. Access to up-to-date information such as pest and disease attacks would also be improved, while the collection of information through networking could easily provide an overall idea of food crop production, as well as comparison of yields in different areas.

Livestock extension officers would be able to compare activities of farmers in different regions as well as the problems faced by farmers. Linking computers through a network would help officers put ideas together to bring solutions to problems at farm level. All livestock extension officers agree that it is important for them to be connected through a computer network to other extension offices, the central office, and other divisions such as Dairy Chemistry Division, Veterinary Division and the Agricultural Marketing Board.

The majority of sugarcane extension officers (93) are of the opinion that a computer network linking extension offices (FSC and MSIRI) is important to them. The main aim of this network will facilitate information flow, that is, extension officers will have ready access to information on sugarcane and they will also be able to share information and experience among themselves. A computer network will also help the extension officer give advice to a sugarcane planter growing sugarcane in different areas of the island since all the information on that particular farmer will be available on a computer. Furthermore, extension officers will be able to compare sugarcane production data in different regions of the island.

Perception of constraints to the application of IT in extension in Mauritius

Extension officers ranked the constraints that might hinder the application of IT in extension. Training of extension officers constitutes the most important constraint (89) to be overcome before IT can be applied in Extension. Other constraints include lack of familiarity of extension officers with computer and lack of infrastructure (Table 11).

Table 11 Obstacles to application of IT in Mauritius

Obstacles	% Respondents		
	Agree	Not sure	Disagree
Training of extension officers	89	11	
Lack of familiarity with computers	60	25	15
Lack of infrastructure	59	22	19
Lack of information to create a database	41	4	55
Lack of legal framework	35	42	23
Financial Constraints	7		

DISCUSSION

The practice of extension in Mauritius

The survey of the extension officers at the end of 1997 confirms that the target audience for each institution is clearly defined. It has also been established that extension officers are predominantly male, two-thirds below the age of 45 years. However, a recruitment exercise was under way at the time of the survey at the AREU, in line with the role it is expected to play in promoting agricultural diversification in Mauritius and in increasing agricultural productivity at the national level (MANR 1995a), dealing with around ten thousand livestock keepers and a similar number of food crop growers.

The Extension Division of the Mauritius Sugar Industry Research Institute and the Farmers' Service Corporation, being the two organisations involved in sugarcane extension, while the Agricultural Research and Extension Unit is responsible for extension in the non-sugar crop and livestock sectors. The latter institution is expected to play an important role in modernising and revitalising agriculture locally. The frequency of visits to farmers by extension officers varies depending on the field of extension. Thus, crop extension visits are mostly (90) carried out on a fortnightly basis while livestock extension officers (75) visit farmers at intervals longer than monthly. This can be explained by the fact that most vegetable crops are short cycled and therefore farmers require more frequent visits of extension officers whereas rearing of livestock does not necessitate frequent visits of extension officers unless the farmer is faced with difficulties. Sugarcane extension officers visit sugarcane planters either fortnightly or at longer interval depending on the cultural practices adopted and the time of the year.

Individual meetings are the preferred method of carrying out extension rather than group meetings. Information is most of the time provided as personal communication. This ensures that the farmer receives the correct information from the extension officer in an appropriate form. Publications are also given to farmers; however, this format is not appropriate to farmers who are illiterate, hence reinforcing the importance of personal communication. Group meetings are also effective to disseminate agricultural information. Thus, in the sugarcane sector, large group meetings are held on monthly basis, possibly as a strategy to satisfy the 35000 small sugarcane planters.

In addition, farmers especially crop growers and livestock breeders, usually call at the office to meet extension officers when faced with a particular problem. Moreover, a larger number of farmers are now using the phone to get in touch with the extension officers, also demonstrating that farmers are adapting to the development in communication technology.

Information exchange in extension

Extension is playing its role of providing the link between the researcher and the farmer whereby the results of research are communicated to farmers as well as feedback on the problems faced by farmers to researchers, examples of both having been found during the survey. Extension officers have to deal with a wide range of types of information and therefore have to be well informed on technical, economic and social aspects of farming to advise farmers. They generally obtain such information through their own reading, their peers and through publications but only a small proportion (22) currently obtains information from the Internet. This is expected to rise in future.

Generally, extension officers are in a position to answer queries of farmers on the spot and sometimes the answer to the query may be available but is not readily accessible. However, extension officers cannot provide answers to the farmers 10 and 22 of the time, in sugarcane and crop extension respectively, until further research is carried out. The lower figure in the case of sugarcane extension may be due to the fact that research in sugarcane has been geared towards the needs of farmers while crop extension has to deal with a larger array of crops.

Scope of information technology applications in extension

Extension officers are also aware of the potential of information technology to provide a variety of information ranging from information on crop and animal husbandry practices, information on pest occurrence to information on current research projects. Overall, they have a positive attitude towards IT applications in their field of work.

Half of the extension officers have access to computers at the office. However, these are mainly sugarcane extension officers at the MSIRI and the FSC, which demonstrates a difference in the exposure to information technology at the level of the institutions in Mauritius. Furthermore, the extension officers who actually use the internet are those having access to computers at the office, possibly indicating that exposure to the technology leads to further exploration of its uses and applications.

More than half of the extension officers have already followed courses in IT and about two-thirds already have the basic skills required to use a computer. Therefore, these extension officers would be able to use an agricultural information system developed around the concept of the World Wide Web, which uses a graphical user interface, as proposed by Bheenick (1998). Such a system allows up-to-date information to be obtained rapidly and often simply by making use of relevant keywords. The web also has the ability to link up relevant information located on the Internet. Therefore, the ability of IT to provide information rapidly to a large audience makes it an appropriate tool to facilitate communication in extension.

Furthermore, fifty five percent of extension officers are interested in following courses in information technology. Further training, especially of the younger generation, will allow extension officers to use information made available to them through IT. Moreover, these extension officers would be able to evolve together with the new technology being developed as well as contribute to the information system during their career.

Information technology can have a major role in communication and exchange of information in extension. Generally, both extension officers and farmers need convenient access to a wide range of scientific publications (Jones 1990). Such publications are costly to print and take up valuable storage space and therefore electronic publications provide a good alternative. Additionally, electronic publications reduce the dissemination of out-of-date information (Tennessen et al. 1997); dynamic information, such as pesticide information, needs to be updated often and delivered quickly to farmers from researchers. Moreover the advent of CD-ROM technology allows a large amount of information to be stored in compact discs enabling extension officers equipped with portable computers to provide information to farmers in the field.

While extension officers get access to up-to-date information from researchers to provide to farmers, it is also essential that researchers obtain feedback information from farmers via extension officers. Bheenick (1998) proposed that all agricultural institutions set up local area networks (LAN) to improve

internal communication and that extension offices and other relevant agricultural institutions be linked through a computer network to further improve communication such as sharing and exchanging of information among extension officers. Therefore, an information system developed together with the user-friendly interface will help manage information in agriculture and hence allow sharing of ideas within the agricultural community possibly even bridging the link between farmers and researchers.

The setting up of an integrated agricultural information system will be helpful not only to extension officers but also to users of agricultural information including farmers, cooperative societies, governmental organizations, researchers, students and policy makers. Progressive farmers who are willing to use this integrated information system will, no doubt, benefit from such a system. They will have access to the appropriate information at the right time, allowing the right decisions to be made, which will consequently lead to an increase in agricultural productivity.

An eventual use of e-mail for communication could allow information to be received even in the absence of the computer user and stored until the user reads it, hence ensuring that the information is transferred to the individual, whether he is a researcher, extension officer or farmer. In addition, through the networking of computers, data entry concerning agricultural production for different regions made in different extension offices around the island can provide an overall idea of agricultural production and enables comparisons of production within different areas in Mauritius.

Therefore, the study seems to indicate that there is already an opportunity and a lot of potential for the use of IT by extension officers in Mauritius. In fact, the survey has also established that information technology could be of use in satisfying the information requirements of extension officers and farmers in their field of work in the short term. The specific examples of applications in extension are discussed below.

Scope of IT applications in crop and sugarcane extension

The most important information required by crop and sugarcane extension officers and which can also be provided by IT is information on crop husbandry and management practices. The commonly raised issues by crop and sugarcane growers include control of pest and diseases, weed control, land preparation and other cultural practices. Furthermore more than half of crop and sugarcane extension officers would like to have such information on a computer. Information on these aspects of sugarcane is available through the SIRITELL information system developed at the MSIRI, with new modules to be added in future.

Information on crop husbandry and management of non-sugar crops grown locally is already available in printed form (MANR 1995b) and also in publications of the extension unit of AREU. This information could be made available to extension officers electronically, through an information system, making it readily accessible and easier to be kept up-to-date.

Having access to information on new technology developed for the agricultural sector and reports of research findings are very important to most extension officers. One of the roles of extension officers is to transfer new technology from research to farmers. Therefore, it is essential that extension officers have quick and ready access to such information to be able to give the necessary information to farmers. Crop and sugarcane extension officers would like to be provided with results of research (96) and information on new technologies available (84) through an information system.

Extension in Mauritius does not provide market information (demand, supply and prices of food crops) to farmers, as is practiced elsewhere (Kleps and Absher 1997). Hence, it is difficult to plan crop production, resulting in prices of agricultural products fluctuating according to demand and supply. In some cases, farmers are not able to recuperate their investment if prices fall too low. Crop growers often raise this issue with extension officers (50) implying that farmers require such information. Given that extension officers are in contact with farmers, a database containing information on crops grown by farmers can be used to predict yields of different crops at any one time. In this way, crop production can be controlled to satisfy the market demands. However, this will require the collaboration of farmers, as they will have to provide correct information such as area under cultivation and costs of their production.

One of the roles of an extension officer is to assist farmers in decision-making at the farm level. The extension officer should therefore master technical, economic as well as social issues so as to be able to provide sound advice to the farmer. Moreover, crop and sugarcane extension officers mention that a potential use of computers in extension would be to provide timely and up-to-date information for decision-making. Therefore a computer database containing information on the farmer and the previous practices adopted by the farmer and an information system containing important aspects of crop husbandry, results of research and new technologies will help extension officers provide the correct information so that farmers take proper decisions.

Information technology is concerned with the storage, processing and dissemination of information. Information plays an important role in planning and decision-making. Hence the availability of a large amount of reliable information will assist in planning. For example, one of the problems currently faced by many crop growers is the lack of seeds and planting material. Therefore, it is essential that authorities take the proper steps to ensure that the amount of planting material that will be required by growers is available. To be able to achieve this, the authorities should have basic information such as the number of growers in Mauritius and the area under cultivation of specific crops. Such information can be stored and made available rapidly through IT to facilitate planning.

Scope of IT applications in livestock extension

Although there are only a few livestock extension officers, they provide an insight of the information needs of extension officers and farmers in this field. Fodder shortage is one of the major issues raised by cattle keepers as well as a major area of research locally. A better planning strategy can help to solve the problem of fodder shortage. Moreover, extension officers deal with a range of livestock animals including cattle, poultry, goat, pig and sheep, each having its own specificity as far as feeding is concerned. To be able to recommend appropriate feeding management, extension officers require information on types and quantities of feed so as to be able to plan for adequate feed supply. Hence, it is beneficial to have such information on an information system. Moreover, any results of research concerning feeding of livestock can be up-dated when available on an electronic format on the computer. A similar approach could be used to solve the problem of a lack of animals for purchase, following importation by government services.

Livestock keepers rarely ask extension officers for information on diseases affecting livestock but 67 of livestock extension officers find it useful to have such information on an information system. This may be because problems of diseases in livestock are usually dealt by the veterinary services of the Ministry of Agriculture. However, extension officers would at least need to identify diseased animals so as to recommend the advice of veterinary services. Information on diseases of livestock such as symptoms of common diseases is already available in local publications of the livestock extension and can be supplemented with the help of veterinary services so that it can be provided in electronic format on a computer to extension officers. In addition, coloured graphical displays, illustrating the disease symptoms, can be made available on a computer

Half of the livestock extension officers consider information on housing conditions of livestock important and believe it should be provided to them through an information system while the other half have acquired such information through working experience. Thus new technology developed or results of research in this subject can be made available to the extension officers through an information system and such information on housing conditions would be beneficial to newly recruited extension officers who have not yet gained such experience. Information on housing conditions for different livestock is already available locally in publications of the Livestock Extension Unit and can be used as a basis to create such an information system.

Information on prices of feed and other inputs are considered by half of the livestock extension officers as important information, which can be provided by a computer. The other half of extension officers do not consider places where inputs can be obtained as an important information for extension officers as farmers do not ask them for such information. However to achieve a higher agricultural productivity, it is essential that farmers invest in inputs such as feeds. Therefore, the extension officer's role is to provide information on sources and prices of inputs to farmers to encourage them to consider these options. Hence information technology can be used to store such information so that it can be made available to farmers by extension officers.

Obstacles to IT applications in Mauritius

The survey has shown that the information required by farmers and extension officers locally can be provided by information technology applications, especially those that are in greater demand, such as information on husbandry and management practices, information on research carried out and new technology available to farmers, market information, and information for decision-making at the farm level. However, even though the government is committed to introducing information technology at the national level, the introduction of IT in extension in Mauritius will depend largely on the commitment of the institutions involved. Therefore, these institutions will have to devise Information Technology strategies to overcome current obstacles dealing with issues such as training, infrastructure, appropriate human resources, and the adoption of a policy on information sharing.

Training of extension officers is necessary before IT can be applied locally; 89 of extension officers believe that they need training to make good use of a computer, of which 53 also lack familiarity with computers. However, a graphical user interface (GUI) that makes use of the 'point and click' concept to issue commands does not require much computer skills and extension officers will not find great difficulty to use a GUI. In fact, some of the extension officers who have access to a computer at work are already using the Internet to obtain latest information.

In addition, a proper infrastructure is required to apply IT to the extension unit. Extension offices will have to be provided with a computer, a modem and a phone line to be able to be linked to other computers, or even to the World Wide Web. Furthermore, the pace of development in this area is fast. However, it will be of no use waiting any further to adopt the technology and make it generally available. Financial constraints can no longer be considered as important as the technology is getting cheaper and the decision to invest in the equipment depends on the benefits the institution expect to derive from the adoption of IT.

As the rate of adoption of IT in the agricultural sector increases, human resources will be required to develop appropriate systems, as well as for the maintenance of these systems. However, training institutions such as the University of Mauritius can provide the multidisciplinary approach required in the development of a common, user-friendly interface for the information systems and train the necessary human resources. However, the major obstacle to the application of IT remains the adequate exchange of information among institutions. Databases that will be developed may contain a lot of personal information on farmers, which may be a concern for the individual citizen. Therefore, the process of applying IT in extension will require a policy decision on behalf of the institutions and the Ministry of Agriculture as well as to provide a legal framework for such information exchange.

CONCLUSION

The survey has shown that most of the information required by extension officers, and eventually farmers, could be made available through IT. The information ranges from information on crop and animal husbandry, results of research such as new technology developed, to market information. Moreover, IT can provide information for decision-making both at the farm level as well as at the policy formulation level. Most of the information required for the creation of an information system is already available but is not currently in a structured electronic form that can easily be accessed. For example, information such as market information is not presently accessible but the creation of a database with the collaboration of farmers, providing up-to-date information regularly could provide information on the demand and supply of crops. Furthermore, information on research carried out locally and new technology can be updated and disseminated rapidly when available on a computer.

Information technology offers the advantage of providing up-to-date information required by extension officers rapidly, increasing the efficiency of the extension services. Hence, IT applications will help extension officers and farmers make good decisions. IT also offer the ability to link up the information held up at different agricultural institutions so that a wide range of information is available at any time. The evolution of information technology in extension can also, in the future, lead to the development of expert systems and decision support systems in the form of simulation models.

Moreover, this survey has shown that extension officers are interested to use IT applications to improve the information flow between researchers and farmers. About two-thirds of the extension officers have a computer literacy level which would allow them to use an agricultural information system with a graphical interface. Therefore, there is scope for the application of IT in extension in Mauritius. However, training will still be required not only for new users of computers but also as their skills in applying IT in their area of work evolves.

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THE PROMOTION OF EFFICIENT WEED MANAGEMENT TO IMPROVE SUGAR CANE PRODUCTIVITY

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ABSTRACT

Inefficient weed control is a major constraint to productivity among sugar cane growers. An on-farm trial was set up to compare weed management practices recommended by the MSIRI with those of a model planter chosen among a group of seven planters growing about 300 ha of sugar cane in the super-humid zone. The choice of herbicide, timing of application and spraying techniques were the targeted areas. Results showed an increase in yield and a reduction in the cost of herbicide application by the adoption of MSIRI recommendations. The trial has highlighted the role of extension in the promotion of new technologies developed by research to increase productivity.

Keywords: On-farm research, productivity, sugar cane, *Saccharum officinarum*, weed control, technology transfer, extension activities, Mauritius

INTRODUCTION

The sugar industry has for years been the backbone of the Mauritian economy. At present it is the second foreign income earner of the country (MEPD, 1996). The liberalisation of trade as administered by the World Trade Organisation (WTO) will force Mauritius to improve its competitiveness by increasing its productivity. The adoption of novel techniques by traditional farmers is a means of achieving this objective. Planters are categorised according to the area they cultivate: Small planters cultivate < 10 hectares, medium planters between 10 and 42 hectares and large planters > 42 hectares. In Mauritius 50 % of cane land is cultivated by miller-planters, 15 % by large and medium planters and 35 % by small planters. During visits to large and medium-planters, weed management was identified as an area where extension could play an important role in increasing sugar cane productivity. Planters complained about the inefficacy of herbicides: In spite of the amount of herbicides used (three or even four applications per year) they still had to resort to manual weeding. Inquiries about their weed control practices revealed the following:

- Incorrect timing for weed control, e.g. weeds removed at late flowering stage, often after seed dispersal,
- Use of inappropriate herbicides for the control of certain weed species,
- Incorrect method of application: with appropriate nozzle, erratic walking speed,
- Non-respect of the recommended dosage.

A trial was laid down on a medium-planter's farm in the eastern sector of Mauritius to demonstrate correct weed control and other cultural practices in view of reducing production cost, decreasing the competition between weeds and sugar cane and minimising the dependence on manual labour. This planter was to serve as a model for other planters and extension officers. The distribution of the different categories of planters in the eastern region of the country as well as the institutions responsible for extension are detailed in **Table 1**.

Table 1. Distribution of planters in the different categories in the east, and institutions responsible for extension.

Area ha	Category of planter	No. of planters	Total area ha	Institution
< 10	Small	10 451	6 993	FSC
10 – 42	Medium	49	863	MSIRI
> 42	Large / Miller	6	11 343.	MSIRI

Source : 1995 Sugar Insurance Fund Board Data
 FSC: Farmers' Service Corporation
 MSIRI: Mauritius Sugar Industry Research Institute

MATERIALS AND METHODS

The trial was established at St Julien d'Hotman situated in the superhumid zone of the island (mean annual rainfall 2800 mm, soil type: Latosolic Brown Forest), in a field heavily infested by weeds, on an area of one hectare. Weeds present at the outset of the trial are given in **Table 2** and the predominant ones are highlighted in bold type. The whole field received a pre-planting herbicide treatment with glyphosate at 2.5 kg a.e ha -1-1 eight weeks prior to planting, followed by a spot application 4 weeks later to eliminate remaining weeds. A single fertiliser application based on results of soil analysis was made at planting according to the recommended practice.

Table 2. Weeds present at the outset of the trial.

Botanical names	Vernacular names	Botanical names	Vernacular names
<i>Ageratum conyzoides</i>	Herbe de bouc	<i>Oxalis corniculata</i>	Petit trèfle, petite oseille
<i>Alternanthera sessilis</i>	Brède emballage	<i>Oxalis debilis</i>	Oseille, trèfle
<i>Amaranthus dubius</i>	Brède malabar	<i>Oxalis latifolia</i>	Oseille, trèfle
<i>Artemisia vulgaris</i>	Brède chinois	<i>Panicum maximum</i>	Fataque
<i>Bidens pilosa</i>	Villebague	<i>Paspalum dilatatum</i>	Herbe codaya
<i>Bothriospermum tenellum</i>	Botrice	<i>Paspalum paniculatum</i>	Herbe duvet
<i>Colocasia esculenta</i>	Songe, songe blanc, sauvage	<i>Paspalum urvillei</i>	Herbe cheval
<i>Cynodon dactylon</i>	Chiendent	<i>Phalaris arundinacea</i>	Herbe mackaye
<i>Cyperus esculentus</i>	Souchet comestible	<i>Phyllanthus tenellus</i>	Petit tamarin
<i>Cyperus rotundus</i>	Herbe à oignons	<i>Plantago lanceolata</i>	Plantain, herbe caroline
<i>Digitaria horizontalis</i>	Gros meinki	<i>Portulaca oleracea</i>	Pourpier
<i>Digitaria timorensis</i>	Meinki	<i>Setaria barbata</i>	Herbe bambou, herbe bassine
<i>Gnaphalium indicum</i>	None	<i>Setaria pallide-fusca</i>	Millet sauvage
<i>Kyllinga bulbosa</i>	Petit mota	<i>Sida acuta</i>	Herbe panier
<i>Lobelia cliffortiana</i>	Brède mamzelle	<i>Solanum nigrum</i>	Brède martin
<i>Mimosa pudica</i>	Sensitive	<i>Sonchus asper</i>	Lastron piquant
		<i>Youngia japonica</i>	None

Source: Mc Intyre (1991)

The trial was planted on 4 April 1995. The statistical design was a completely randomised block with three weed management treatments, replicated four times. The plot size was 800 m² and consisted of 14 cane rows spaced 1.5 m apart.

Treatment I consisted of a mixture oxyfluorfen + diuron applied in pre-emergence of cane and weeds. This was followed by a second treatment of acetochlor + atrazine + Actril-DS four months later before canopy formation. In year two, hexazinone + diuron + Actril-DS was applied 4 weeks after harvest **Table 3**. Hand-operated knapsack sprayers with double cone jets delivering 640 L ha⁻¹ spray solution were used. Two passages were made per interrow at a walking speed of 0.75 ms⁻¹. Spraying was supervised by MSIRI officers.

Table 3. Dosage and dates of herbicide applications in treatment I

Date of application	Herbicide used	Dosage a.i or a.e kg ha ⁻¹
10-Apr-95	Oxyfluorfen (Goal) + Diuron (DCMU)	0.5 + 2.0
10-Aug-95	Acetochlor (Harness) +	2.0
	Gesaprim (Atrazine) +	2.5
	2,4-D ester + loxynil(Actril DS)	1.3
18 July-1996 (4 weeks after harvest)	Hexazinone (Velpar) +	0.6
	Diuron (DCMU) +	2.1
	2,4-D ester + loxynil(Actril DS)	1.3

Treatment II was the farmer's standard practice, namely, acetochlor + diuron in pre-emergence of weeds. Spraying was done using defective flood jet nozzles with one passage per interrow. The walking speed of the men operating the sprayers was quite erratic. This first application was followed by two post-emergence applications of acetochlor + atrazine + Actril-DS in year one. In year two, the same pre-emergence treatment as year one was applied followed by one post-emergence application.

Treatment III was manual weeding. This operation was performed three times in year one as well as in year two.

Table 4 summarises the number of herbicide applications and manual weeding in the different treatments for the first two years. Regular weed assessments were made in the three treatments at monthly intervals using the frequency abundance method (Rochecouste 1967). The trial was first harvested after 14.5 months in 1996; for each plot, two cane rows of 10 m were weighed to determine the yield. In the first ratoon the trial was harvested, using the same method as above, after 12 months on 25 June 1997.

Table 4 Number and cost of herbicide applications and manual weeding in each treatment

	Year	Herbicide applications		Manual weeding
		<i>Treatment I</i>	<i>Treatment II</i>	<i>Treatment III</i>
No. of Treatments	1995	2	3	3
	1996	1	2	3
Herbicides	Cost MUR ha ⁻¹	3 812	5 154	-
Labour		1 200	1 950	-
Treatment total		5 012	7 104	7 608

MUR 25 = USD 1

The extension methodologies used were:

- Regular visits with planters of the region on site of experimentation,
- One visit with all planters of the sector,
- Diffusion of a video clip on the trial during meetings with large- and medium-planters,
- Discussions on the trial during group meetings with planters and meetings with Farmers' Service Corporation managers.

RESULTS

Weed control

The weed abundance in the three treatments before canopy closure is given in **Table 5**. Weeds were kept under control for about 3.5 months with treatment I. The few weeds that emerged thereafter received a second herbicide application before flowering, resulting in a decrease in weed infestation. This was sufficient to keep the plots clean until harvest. Due to the proper monitoring of herbicide application in the first year, only one application was necessary in year two to maintain the field reasonably clean until canopy formation.

In *treatment II*, weeds were kept under control for only 1.5 months after application of pre-emergence herbicide in year one. Two additional post-emergence treatments were necessary before canopy closure. In the second year, herbicides were applied twice.

In *treatment III* (manual weeding) the field was never free from weeds for more than a few days. Sugar cane in these plots was constantly in competition with weeds.

Table 5 Weed abundance in the different treatments before canopy closure in 1995

Months after application	Weed abundance expressed as % of manual weeding		
	<i>Treatment I</i> MSIRI	<i>Treatment II</i> Planter	<i>Treatment III</i> Manual weeding
1	5	25	100
2	10	40	100
3	15	55	100
4	22	20	100
5	2	35	100
6	5	45	100

Appropriate weed control strategies, as demonstrated in *Treatment I*, resulted in a decrease in the number of herbicide applications, hence reducing the cost of production **Table 4**.

Cane growth and yield

During the elongation phase, cane growth was most vigorous in *treatment I* and least in *treatment III*. In *treatment I* where there was no weed competition, a significantly higher cane yield was obtained in 1996 as compared to the other two treatments **Table 6**.

Table 6 Effect of herbicide treatments on cane yield

Treatment	tons ha ⁻¹	
	20-Jun-96	26-Jun-97
I. MSIRI	91	123
II Planter	78	106
III Manual Weeding	71	95
SE ±	3.3	2.4

The same trend was observed in the ratoon crop in 1997. The difference in the mean yield between *treatments I* and *II* for the two years was 15 t ha⁻¹ which is equivalent to about 1.65 tons of sugar per year with a mean extraction of 11%. Being given that the planter received an average of MUR 8000 t⁻¹, he thus obtained an additional revenue of about MUR 26 000 ha⁻¹.

DISCUSSION

The reduction in the number of herbicide applications by proper weed management, as indicated in **Table 4**, decreased the cost of labour. The ability to save on that resource will definitely benefit the local sugar industry. In *treatment II*, the non-uniform soil coverage with herbicide, due to defective spraying, contributed to the emergence of other weed generations.

Manual weeding is not only tedious but also ineffective. Regrowth is fairly rapid and abundant in superhumid areas, hence the cost of hand weeding is very high (MSIRI 1971), encouraging farmers to resort to chemical weeding.

The lower cost of herbicide in *treatment I* compared to *treatment II* was due to a reduced number of applications, since the amount of fertile seeds kept on decreasing when weeds were controlled before flowering stage.

The use of herbicide with longer lasting action like oxyfluorfen has also contributed to reduce the number of applications. Although this type of herbicide is more expensive, a reduction in the number of applications decreased the cost of herbicide use and was therefore more cost-effective **Table 4**. The difference in yield between the different treatments was due to consumption of fertilisers by weeds and competition for light in the early growth stages of the cane; light being often limiting in the superhumid region of Mauritius. The long term mean radiation (sunshine hours) for the superhumid area is 187 as compared to 238 for the Northern coastal region, that is about 20% less in the region where the trial was laid down. The high weed incidence and the delay in controlling the weeds led to a significant decrease in yield in *treatment II*. In the control plots (*treatment III*) where weed abundance was greater than in *treatment II*, the yield was even lower. The results have shown that cane yield can be increased by adopting MSIRI recommendations.

Weed control was identified as being the main problem for almost all small- and medium-planters in Mauritius. The area cultivated by small- and medium-planters is about 34 500 ha and the potential of producing additional sugar by efficient weed management cannot be ignored.

One of the most widely used models for farmers-scientist interaction is “farmer-back-to-farmer” which was formulated at the International Potato Center in the early 1980s. This model was based on the assumption that agricultural research and development must both begin and end with farmers - that they must be involved at all stages, from diagnosis to evaluation of results (Rhoades 1994). The planter's participation was obtained from the beginning to the end of the trial and was an essential tool for extension since planters are more willing to adopt practices that have worked in other planters' fields.

The transfer of the new practices was achieved by regular meetings with planters in the region at the site of the trial. They were able to assess the difference in cane growth for the three weed control approaches at different stages of crop growth. Planters were thus convinced that they could increase their productivity by adopting efficient weed control measures.

Interaction between researchers, extension officers, the model-planter and targeted planters revealed that the following improved practices were subsequently adopted:

- pre-planting treatment with glyphosate,
- use of double cone jets with two passages per interrow,
- adoption of oxyfluorfen in pre-emergence since they were impressed by the results obtained and monitoring of herbicide application.

A video clip of the on-farm trial, which included the views of the model-planter and the researcher responsible for the weed management of the trial, was prepared and diffused to the planting community.

The training of sprayermen was identified as a prerequisite for proper herbicide application and is being implemented through demonstrations and the diffusion of a film on spraying techniques. During group discussions, planters acknowledged that sprayermen were reluctant to shift from their traditional spraying practice to the recommended one because they had to make two passages instead of one, in an interrow. It was found that this constraint could be overcome by an increase in wages, compensated

however by a reduction in the number of applications. Planters became more conscious that efficient weed management could only be obtained through a holistic approach including the proper scheduling of other cultural practices. For instance, derocking cannot be done after application of pre-emergence herbicide (a common practice among planters). The timing of fertilisation is also an important factor to take into account for efficient weed control. In the plots treated by the MSIRI, only one application of fertiliser was done at planting as it has been shown that no advantage is derived from a split application(NgKee Kwong et al 1994,1995). The planter adopted split application which implied walking in the field after a pre-emergence herbicide application hence the film of herbicide covering the soil, thereby causing weed regrowth.

CONCLUSION

Efficient weed management can increase sugar cane yield and decrease weed control costs. Implementation of appropriate weed control strategies should be scheduled with other cultural practices such as derocking and fertiliser application. On-farm trial has allowed other planters to evaluate weed management practices in conditions similar to theirs. The importance of extension in the promotion of new technologies developed by research has been highlighted. The adoption of new technologies such as improved weed management is definitely a means for the country to increase its competitiveness and production so as to fulfil the various commitments on the preferential markets in the European Union and the USA.

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A CRITICAL REVIEW OF PARENTAL CHOICE AND CROSS PREDICTION TECHNIQUES IN THE MSIRI SUGAR CANE BREEDING PROGRAMME

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ABSTRACT

The MSIRI has so far achieved great progress in the production of sugar cane varieties that meet the various objectives of the sugar industry. This derives from a judicious choice of parental varieties followed by the use of appropriate mating systems and selection strategies. These procedures are critically reviewed in the light of future needs. Various methods have been employed to estimate the potential of crosses and the likelihood of selecting crosses that have the greatest potential for producing commercially acceptable genotypes. Consideration is also given to making breeding strategies less subjective and more genetically and statistically based. This is illustrated by the assessment of twenty biparental crosses at the preliminary stages of selection over two contrasting environments.

Keywords : breeding methods, breeding value, heritability, hybridisation, selection, sugar cane, *Saccharum officinarum*, Mauritius

INTRODUCTION

Each year at the MSIRI some 2 500 to 3 000 crosses, representing 500 to 600 genetic combinations, are made involving 250 to 350 parent clones. The object is to produce high yielding varieties with good sucrose content and good ratooning ability, adapted to different agroclimatic conditions, resistant to diseases and pests and suitable for harvesting at different dates and by mechanical means. The parental gene pool comprises 1862 clones and includes basic species, first (F1), second (BC1) and third (BC2) generations of interspecific hybrids, commercial varieties and foreign accessions. Emphasis is laid on the efficient use of parent clones in crosses to generate greater genetic variation and to concentrate greater efforts on those crosses that stand the highest probability of producing elite genotypes, thus improving on the efficiency of production of commercially acceptable varieties. The judicious choice of parents to be used in crossing is a prerequisite for an efficient breeding programme and to sustain genetic progress of future plant generations. The acquisition of further knowledge on the mode of transmission of traits of importance provides another avenue that is helpful in refining choice of parents. Furthermore, increasing use is made of IT systems in the screening of parents for crossing. This paper reviews the different approaches adopted in the choice of parents and cross prediction in the local hybridisation programme.

CHOICE OF PARENTS

The correct choice of parents to be used in crossing will depend largely on the aims and objectives of the breeder and is generally based on phenotypic and genotypic expression of the characters they display. The two main criteria adopted at the MSIRI are as follows: (a) the characteristics of the parents such as agronomic and morphological traits, disease reaction and flowering behaviour and (b) breeding performance of the parents as revealed by progeny tests of previous crosses (Ramdoyal and Domaingue 1994). Genotypes planted in advanced selection trials, i.e. stage 4, and final phase variety trials (Anon 1997), are characterized and evaluated for the following traits: germination rate, vigour, stalk number, stalk diameter, height, growth habit, flowering date and intensity, ratooning ability,

hairiness, trashing ability, cane and sugar yield, disease and pest reaction, adaptation to major environments and microclimates, sucrose content, maturity characteristics and fibre content.

For some specific characters like sucrose content, genotypes from crosses are recycled to the parental genepool as early as possible (stage 3), thus reducing the generation interval. In addition, basic wild and noble germplasm are characterised for major traits to provide a sound basis for their utilisation in the genetic base broadening programme and the introgression of specific characters in commercial hybrids (Anon. 1987,1996). Furthermore, isoenzyme markers have been used to characterise parent clones for sucrose content (Anon 1992).

Information on the performance of parent varieties in previous crosses is derived mainly from the first clonal generation (stage 2), in terms of selection rates and combining abilities. These records have provided important guidelines in the choice of parent clones in crosses (Domaingue et al. 1988). Selection at stage 2 is based on field refractometric Brix (% soluble solids in juice), stalk number and vigour. Selection data of crosses advanced to the first clonal stage for the past 31 years have been preserved in computer files. This has enabled the calculation of selection rate of each cross on a yearly basis and computation of cross ratios i.e. the proportion of genotypes selected in each cross divided by the overall mean proportion of genotypes selected from the whole population, which is roughly taken as 15%. These cross ratios are converted into a two digit grade x/y such that 'x' represents the cross ratio which broadly reflects specific combining ability (SCA) on a scale highest to lowest 1 to 5 and 'y' represents the population of progeny measured for the family, on a scale of 1 to 5 (Domaingue et al. 1988). The mean of cross ratios for a parent in all crosses in which it appears across years broadly reflects its general combining ability (GCA). Likewise, the GCA values are converted into a two-digit grade (x/y) where 'x' represents GCA and y represents total population of progeny measured for the trait (Domaingue et al 1988).

However, there is a need to calculate cross ratios from the latest stage of selection reached by a cross because some crosses may have high selection rates at the preliminary stage owing to high sugar content but few of the clones are selected at the advanced stages of selection because of poor cane yield as advocated by Walker (1962) and Arceneaux (1968).

In most sugar cane breeding programmes there has been little effort made specifically to produce parent clones; the basic approach adopted is that a good variety is somehow equivalent to good genetic composition that will automatically be a good parent in crosses in terms of giving rise to genotypes that will be commercially acceptable. This is not always a good assumption because not all commercially grown varieties are necessarily good parents (Caligari 1992; Bradshaw and Mackay 1994; Ramdoyal and Domaingue 1994). Over the past decade, the MSIRI has placed more emphasis on the production of source populations for instance, there is a recurrent selection programme for the production of high sucrose parents (Anon 1995). The recycling of parents in crosses from stage 4 selections (5-m line plots replicated twice) is another form of recurrent selection programme currently in use.

It is not always possible in practice to utilise the most promising varieties as parents, because of genetically and environmentally induced sterility of varieties, incompatibility barriers and low pollen viability of male varieties. In addition, there are often problems of asynchronous flowering, although these have been solved to a certain extent by the use of artificial light treatments, particularly in the wild species, to delay flowering in varieties that flower very early in the season (Julien 1970; Badaloo et al. 1995). Studies are currently being carried out to induce flowering under artificial conditions (Anon 1997) and new collections of parents are being continuously established in lowland warmer environments to increase pollen fertility status of male parents (Anon 1996). Furthermore, male varieties are systematically tested for pollen fertility, using Alexander's stain, to rationalise their use in crosses (Anon 1996,1997). These approaches are expected to help in increasing the efficiency of choice of parents for utilisation in the hybridisation programme.

MATING SYSTEMS

In the planning of crosses, the main mating systems available are the proven cross and the proven parent both based on progeny performance and proven variety performance (Heinz and Tew 1987). The performance of each cross is assessed and if any given cross has performed sufficiently well, it is called a "proven cross".

The proven status of a cross is assessed by a cross ratio analysis based on selection rates at preliminary or better still at advanced stages of selection (Heinz and Tew 1987). For each cross, it is common to use a selection rate (proportion of genotypes that are retained from the initial population based on specific criteria such as: breeder's preference and cane and sugar yield) which integrates all factors such as: mean, variance and type of distribution (Skinner et al. 1987). As selection rates are subject to large environmental effects when single stools are grown in large seedling and first clonal populations, it is useful to determine relative selection rates in the clonal selection stages (Breaux 1987; Berding and Skinner 1987). The proven parent approach is based on the intercrossing of female and male parents of high breeding performance (Ramdoyal et al. 1998) and aims at increasing the probability of selecting superior genotypes with acceptable commercial attributes. The proven parent approach, as practised locally also exploits the intercrossing of male and female parents, with high breeding performance as 'testers' in crosses with clones on which information on breeding performance is lacking.

In the MSIRI breeding programme, the proven variety mating system makes extensive use of elite varieties which are the promising clones in final phase variety trials. Tew (1987) found that the use of new elite clones as parents in crossing resulted in an increased rate of genetic progress in Hawaii. In addition, Warner (1953) and George (1962) found an increasing frequency of superior seedlings with successive generations of elite hybrids as opposed to repeating the crosses between the original parents. At present, there is no complete agreement among sugar cane breeders on the relative merits of the different strategies. According to Breaux (1987), many sugar cane breeding programmes, using their own criteria of evaluation, make considerable and consistent progress by careful parent selection, followed by selection of elite families and liberal selection of individuals in the seedling and early clonal stages.

The practice of repeating past crosses that have given high percentages of selection and the continuous testing of increasing numbers of seedlings from such genetic combinations with the hope of selecting superior genotypes is believed to be unreliable. Greater advance and response to selection will be achieved from the selection of seedlings arising from new parent combinations as suggested by Warner (1953) and George (1959). George (1959) found repeating crosses are hardly worthwhile after having already evaluated 2000-3000 seedlings.

In practice it would seem that even 500 to 600 individuals per genetic combination would suffice to test for superior genotypes and to get a reliable idea of the worth of families (Kearsey 1997, Pers. Communication). As knowledge about the mode of inheritance of important traits has improved, there has been a concomitant increase in efficiency of parental selection and cross evaluation in the local breeding programme (Hogarth et al. 1981; Domaingue 1988; Mamet et al. 1996; Badaloo 1997a; Bissessur 1997; Ramdoyal and Badaloo 1998). Furthermore, Ramdoyal and Badaloo (1998) and Badaloo et al. (1997) p35 -59, working on biparental progenies, observed substantial additive genetic variance compared to non-additive genetic variance for many characters at the preliminary phase of selection. Thus, judicious use is made of both general and specific combining abilities by the evaluation of parents based on the results of their progeny from several years.

IT SYSTEM IN PARENTAL CHOICE

Although the ultimate choice of varieties to be used in crosses is made by the breeder, the availability of a customized IT system is of tremendous help in increasing the efficiency of parental choice and in assorting parents in crosses (Ramdoyal et al. 1998). Databases are available in which each parent is coded for agronomic traits, morphological attributes, disease reaction, flowering characteristics and breeding performance (Ramdoyal and Domaingue 1994; Ramdoyal et al. 1998). For the formulation of crosses for a specific agro-climatic zone the system requires that at least one of the parents is adapted to the specified zone and resistant to major diseases prevailing in that zone. Similarly, computer programmes take care of combining abilities in screening for proven crosses and for the judicious use of clones of good combining abilities (Ramdoyal et al 1998) in test crosses or proven parent crosses.

POTENTIAL OF THE MOLECULAR APPROACH

Molecular characterisation of parent varieties should be feasible with the rapid progress in the field of molecular genetics and biotechnology. This will provide useful information on existing genetic diversity and will allow a more rational use of the parental genepool. One of the direct benefits of molecular markers, once the feasibility of marker assisted selection for traits of interest in the parent genepool e.g. sugar content, adaptation and yield is established, will be to help breeders rapidly select superior parents for use in crosses and therefore to reduce the generation interval and allow a faster recycling of new parents in the genepool.

CROSS PREDICTION

In Mauritius, various attempts have been made to identify the best crosses in terms of their potential to produce commercially acceptable varieties. Thus, George (1959) utilised the frequency distribution curves of agronomic traits, by measuring random samples of seedlings/cross, to assess the merit of each cross. He applied a visual grade score to represent the relative worth of individual seedlings so that the family mean of such ratings bears a close relation with the mean cane yield per family. George (1962) also reported that very poor genetic combinations could be discarded on the basis of their average performance. Progeny testing has been done on interspecific seedling families, i.e. F1, BC1 and BC2, since the late 1980s, based on thirty progeny per family and recording of stalk number, stalk diameter, vigour, growth habit, Pol, fibre and dry matter, in order to provide a more rational way of selecting parents and crosses (Ramdoyal and Domaingue 1994).

Recently, Badaloo et al. (1997, p138-168; p169-180) working on 20 biparental progenies in two contrasting environments (Belle Rive and Pamplémousses) and over the seedling, the first and second clonal generations, with 120, 55 and 24 genotypes/family respectively, assessed the potential of univariate and bivariate cross prediction techniques in the local breeding programme. The mean and square root of the phenotypic variance of each cross were used, according to the methodology of Jinks and Pooni (1976), to calculate the predicted proportion of genotypes that are expected to be $\geq$ or $<$ the set target (PROB) for each trait. The PROB was compared to the observed proportion of genotypes that exceed the target (OBS) and the family mean (MEAN). Bivariate prediction was based on the methodology of Pooni and Jinks (1978) and Brown and Caligari (1988).

In general, there were highly significant positive correlations between the predicted and the observed proportions of genotypes that are expected to transgress the set target for most traits at each generation and at both sites **Table 1**.

In all cases of comparison between the three statistics there was highly significant agreement between them, indicating that there is great scope for using these statistics early in the selection programme to discriminate between crosses.

Table 1. Correlation between predicted proportion of elite genotypes at one generation (PROB) and observed proportion at later generations (OBS) for different sites and stages of selection

Trait	Observed at		Predicted from			
	Site	Stage	BR _{SDG}	PSES _{SDG}	BR _{FCG}	PSES _{FCG}
Breeder's Preference	BRES	SDG	0.88	0.46	-	-
	PSES	SDG	0.59	0.74	-	-
	BRES	FCG	0.57	-0.02	0.89	0.08
	PSES	FCG	0.44	0.22	0.01	0.86
	PSES	SCG	-	0.41	-	-
Cane Yield	BRES	SDG	0.95	0.71	-	-
	PSES	SDG	0.62	0.86	-	-
	BRES	FCG	0.42	0.00	0.99	0.27
	PSES	FCG	0.63	0.40	0.37	0.97
	PSES	SCG	-	0.20	-	-

Significance Levels 0.44 @ 5% and 0.65 @ 1%

BRES Belle Rive Experiment Station PSES Pamplemousses Experiment Station

SDG, FCG and SCG refer to the seedling, the first and second clonal generations respectively

In general, breeders are greatly interested in the relative ranking of crosses for characters of importance. There were highly significant correlations between the predicted and observed ranks for all traits studied **Table 2**.

Table 2 : Comparison of predicted and observed rank correlation coefficients of 20 crosses at the seedling stage.

Trait	Correlation	
	BRES	PSES
Breeder's preference	0.86	0.76
Cane yield	0.94	0.82
Growth habit	0.97	0.96
Leaf stripping ability	0.96	0.92

Significance Levels 0.39 @ 5% and 0.55 @ 1%

BRES Belle Rive Experiment Station PSES Pamplemousses Experiment Station

Comparison of correlation coefficients between ranking of crosses showed highly significant correlation between the predicted and observed rankings, between the predicted and mean ranking and between the observed and the mean ranking of crosses for all traits at the three generations at both sites **Table 3**.

Table 3. Rank correlation coefficients of three statistics at Pamplemousses at the simulated second clonal generation.

Trait	PROB/OBS	PROB/Mean	MEAN/OBS
Breeder's Preference	0.80	0.99	0.82
Brix	0.96	0.98	0.94
Cane Yield	0.89	0.99	0.90
Growth habit	0.93	0.99	0.93
Leaf Stripping Ability	0.71	0.99	0.74

Significance Levels 0.39 @ 5% and 0.55 @ 1%

PROB Predicted, OBS Observed

The two bivariate cross prediction methods studied, for Brix combined with cane yield and its components, were (a) The sum of rank (RANK) and (b) the observed frequency of genotypes from each cross that transgress the set targets (FREQ). The RANK was calculated by ranking the 20 crosses, for

each of the two individual variates at each generation and site and then summing them to give a total for each bivariate combination. The observed frequency (FREQ) was derived by counting the total number of genotypes that exceeded the set target for each of the two variates at the same time (Brown and Caligari 1988). In all cases, the correlation coefficients were negative as the lower the sum of ranks the higher the potential of the cross to produce genotypes that exceed the set targets **Table 4**.

Table 4. Correlation coefficients between the sum of ranks and the observed frequency rates for Brix and cane yield components.

Site	Stage	BX/SDIA	BX/SNO	BX/SHT	BX/SWT	BX/CY
BRES	FCG	-0.83	-0.83	-0.85	-0.71	-0.78
PSES	FCG	-0.66	-0.77	-0.64	-0.84	-0.75
PSES	SCG	-0.89	-0.73	-0.84	-0.92	-0.83

Significance Levels 0.39 @ 5% and 0.55 @ 1%

BRES Belle Rive Experiment Station PSES Pamplemousses Experiment Station

BX Brix, SNO stalk number, SHT stalk height, SWT stalk weight, CY cane yield SDIA stalk diameter

The results indicate that there were highly significant correlations between the RANK and FREQ for all bivariate characters. These results have led to the large-scale application of the prediction methods on a larger number of crosses in the routine selection programme in March 1998. Thus, a replicated trial involving 50 crosses has been implemented by testing 60 random seedlings per cross, using a Randomised Complete Block Design. It is expected that rapid and reliable information on parent value will be very useful to the breeder for the choice of parents. In addition, family performance based on objective data collection will enable the evaluation and ranking of crosses in terms of their potential to produce desirable genotypes and the subsequent application of family or combined selection.

CONCLUSION

Constant and sustained efforts are made to refine the tools and techniques for the judicious choice of parents and their subsequent use in crosses in order to increase the efficiency of the hybridisation programme. Several approaches have been adopted in selecting parents and the planning and evaluation of crosses in order to produce superior elite genotypes. These are: historical selection records, inherent parental characteristics and breeding performance. The development of a customised IT system, based on relational databases, has greatly contributed in improving the efficiency in planning of crosses. Emphasis will be placed on the use of cross prediction as a new tool in increasing efficiency of the breeding programme. Future progress is expected to result from the application of molecular techniques in the early screening of potential parents. The ultimate aim is to increase the probability of selecting superior elite genotypes that meet the objectives of the sugar industry.

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EFFECT OF DATE OF TRASHING ON CANE YIELD

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ABSTRACT

Cane trashing consists of the removal of dry leaves from the stem and lining all trash on alternate interrows to facilitate harvest and reduce the amount of extraneous matter sent to the mill. In Mauritius, approximately 50% of the area under cane is manually harvested as green cane. Two trashings are usually carried out, one between end of March and Mid-May and a second one a few days prior to harvest. Trials, laid down between 1994 and 1998 to compare two trashings to only one carried out only a few days before harvest, have revealed that an early trashing may lead to a reduction in cane yield. Among possible causes identified were: mechanical injury and shock suffered by the stalk due to removal of partially green leaves, emergence of more water-shoots and suckers and canes broken during trashing.

Key words: sugar cane, cane-trashing, trashing-date, cane yield, Mauritius.

INTRODUCTION

At maturity, the standing cane is composed of 70% millable stalks, 8% cane-tops, 15% green leaves and 7% dry leaves (Evans and Hardy 1946, Rozeff 1994). Cane trashing involves the removal of dry leaves from the stem and lining them on alternate interrows. This operation helps cane-cutters to locate more precisely the base of the stalks and reduces the amount of extraneous matter sent to the mill. Trashing is carried out in most cane fields not burnt prior to harvest or harvested by a chopper-harvester. This represents approximately 50% of the area under sugar cane. Other reasons for trashing cane before harvest include prevention of rooting at the nodes in humid areas, reduction of attack by rats and of the incidence of scale insects and borers.

Although trashing has been practised before 1858 (North-Coombes 1937), its frequency and timing have changed with time. Formerly three trashing operations in plant cane and two in ratoons were common practice (North-Coombes 1993). In the last two decades, due to labour shortage, the number of trashing operations carried out in plant cane has been reduced to two. In both plant and ratoon cane, a first trashing is performed as from the end of March and is followed by a second one a few days prior to harvest. On some sugar estates, where labour shortage is more acute, trashing is performed only once as from April. A trial was initiated in 1993 to study the effect of trash management on cane yield in the super-humid regions (Anon 1993). A significantly higher cane yield was observed in the plots trashed only once, i.e. one week before harvest. Trials have been conducted since 1993 to confirm these results and to establish possible causes. This paper reports on the main findings of these trials.

MATERIALS AND METHODS

The project was carried out in two phases: The first phase consisted of trials conducted between 1994 and 1997 to assess the effect of the two trashing dates on cane yield, damage to cane stalks and emergence of water-shoots. The second phase conducted in 1998, aimed at assessing the effect of different trashing methods on cane growth.

Phase 1

Trials were conducted at 11 sites on four commercial varieties; the characteristics of each trial site are shown in **Table 1**. Experimentation was carried out on both plant and ratoon cane. Treatments were established over 3 years (plant cane + 2 ratoons) at Union Park and Combo 27 and two years (plant cane + 1st ratoon) at Valetta and (1st ratoon + 2nd ratoon) at New Grove. The remaining sites were used for only one crop.

Table 1. Characteristics and details of trial sites

Site	Cane Variety	Soil group *	Rainfall <i>mm</i>	Crop Cycle	Date harvested
Phase 1					
Combo	M 3035/66	F1	2 700	2R	Aug-94
Union	R 570	F1	2 500	6R	Sep-94
Valetta	M 3035/66	B1	3 100	PC	Sep-95
				1R	Sep-96
Union Park	M 1658/78	F1	3 175	PC	Aug-95
				1R	Aug-96
				2R	Aug-97
Combo	M 1658/78	L2	2 700	PC	Sep-95
				1R	Sep-96
				2R	Sep-97
Reduit	M 1658/78	L1	2 400	2R	Oct-96
New Grove	R 570	B1	3 025	1R	Oct-96
				2R	Oct-97
Union Park	M 3035/66	F1	3 175	4R	Sep-96
New Grove	M 52/78	B1	3 175	PC	Aug-97
Brittania	M 3035/66	F1	3 225	3R	Sep-97
Cote d'Or	M 1658/78	F1	3 200	2R	Oct-97
Phase 2					
Pamplemousses	R 570	L1	1 900		
Union Park	R 570	B1	3 500		

* Parish and Feillafé (1965)

The treatments consisted of two trashing dates: T1 & T2. T1 plots were trashed twice (in April / May and one week before harvest). T2 plots were trashed only once (one week before harvest). Trashing was performed manually with the help of a sickle and in the same manner as for commercial plantations. The statistical design used was a complete randomised block with six or eight replicates; the plot size consisted of six or eight cane rows of 100m each at a spacing of 1.6m. The experimental plots were harvested selectively and cane yield was recorded over a sample area of 80 m² (two middle cane rows 25m long).

An assessment of possible damage to each cane stalk was made between two and three weeks after the first trashing in the T1 plots. The number of broken canes, either at the top or base, were counted in the two experimental rows 25m each.

After harvest the number of water-shoots and suckers were counted at Valetta, Combo, Union Park and Union Park. The counts were made in two experimental rows 25m each within one week after harvest. The method used is described in (Mc Intyre and Hardy 1989).

Phase 2

The effect of trashing methods on cane growth was assessed in two trials at Pamplemousses and Union Park (Table 1). Treatments comprised hard trashing (HT) consisting of removing dry and partially-green leaves, soft trashing (ST) where only dry leaves were removed from the stem and a no trashed control (NT). The treatments were carried out in May and the growth of the stalks was measured at three days interval during the first two weeks and weekly thereafter. In each treatment six cane stools were selected randomly from the two middle rows of 25 m each. Cane elongation on each stalk was measured by the difference between a fixed mark (datum) on the stalk and the top-most visible dewlap. To facilitate comparisons between treatments, the mean extension between recording dates was calculated.

RESULTS

Phase 1

Cane yield

For each year of experimentation, the mean cane yields recorded are given in Table 2. Irrespective of year, 4 out of 17 harvest results showed a significant difference in cane yields in favour of T2 treatments (**Table 2**). These differences were observed three times on variety M 1658/78 and once on variety R 570. Although no significant difference was obtained between the two treatments for the remaining harvests, higher yields in the T2 plots were also observed in seven cases.

Table 2 Cane yields

Site	Year	M 1658 / 78			M 3035 / 66			M 52 / 78			R570		
		T1	T2	SE±	T1	T2	SE±	T1	T2	SE±	T1	T2	SE±
Britannia	1997				78	78	1.75						
Combo	1994				66	72	3.84						
	1995	76	86*	2.83									
	1996	63	68	3.39									
	1997	65	71	6.83									
Côte d'Or	1997	68	68	5.04									
New Grove	1996										70	81	1.70
	1997										74	76	6.83
New Grove	1997							64	70	4.58			
Réduit	1996	80	90*	2.10									
U. Park	1995	83	88	3.26									
	1996	34	41*	2.60									
	1997	69	64	2.23									
U. Park	1995				44	53	4.44						
Union	1994										100	100	4.79
Valetta	1994				54	60	3.37						
	1995				70	70	3.71						

T1 Trashing in April / May T2 Trashed one week before harvest

* Significantly higher than T1 @ P=0.05

Broken canes during trashing

At the three sites where an assessment was made, the damage on cane stalks following an early trashing (T1) was negligible irrespective of cane variety (**Table 3**). Breakage seemed to be more pronounced at the base of the stalk.

Table 3. Assessment of damage to cane stalks (% of total number of millable canes)

Site	Cote d'Or	Britannia	New Grove
Variety	M 1658/78	M 3035/66	M 52/78
% of stalks broken at tops	0.3	0.2	0.1
% of stalks broken at base	1.2	4.4	0.3

Water-shoots and suckers

The number of water-shoots in the plots trashed earlier (T1) was significantly higher than in the other treatment (T2) (**Table 4**). No difference in number of suckers was recorded between the two treatments.

Table 4. Effect of trashing date on number of suckers and watershoots

Site	Valetta		Combo		Union Park 3271		Union Park 3254	
Variety	M3035/66		M 1658/78		M 1658/78		M 3035/66	
Crop cycle	1 st Ratoon		Plant Cane		1 st Ratoon		4 th Ratoon	
Year	1995		1995		1996		1996	
	SK	WS	SK	WS	SK	WS	SK	WS
T1	0.51	0.30	1.40*	0.23	4.90	0.24*	0.89	1.00*
T2	0.56	0.26	1.10	0.15	4.60	0.13	0.83	0.66

* Significantly higher than T2 @ P=0.05

T1 Early trashing

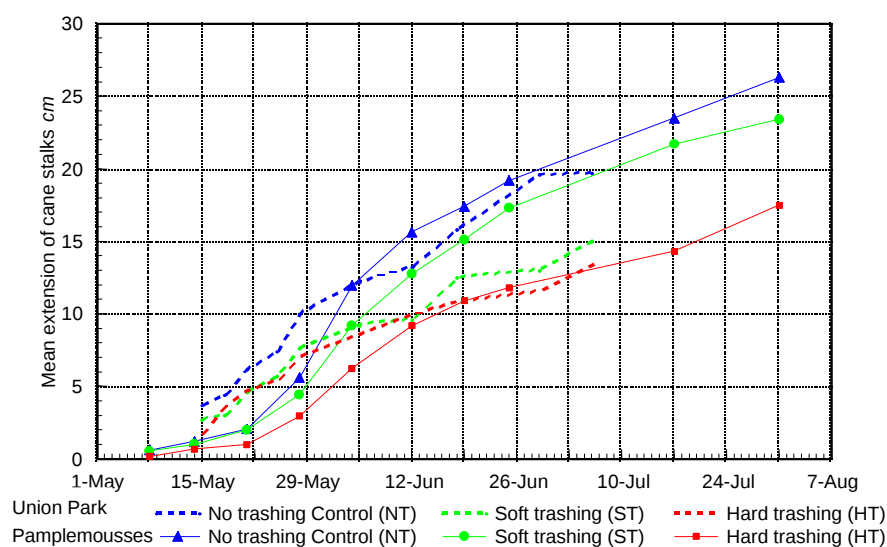
T2 Trashing 1 week before harvest

SK Suckers

WS Water-shoots

Phase 2

The stalk elongation curves indicate that a reduction in growth occurred in plots where trashing was performed at both sites. The effect was more pronounced in the HT plots at both sites, and also in the ST plots at Union Park (**Figure 1**).

Figure 1 Effect of trashing methods on cane growth at Pamplémousses and Union Park

DISCUSSION

Harvest results have shown that trashing in April or May can lead to a reduction in cane yield. The first factor thought to be responsible for this reduction was the number of broken canes during trashing. The negligible number of broken canes recorded at the three sites implies that this factor does not contribute too much to the reduction in yield. The relatively higher number of broken canes at the base with cane variety M 3035/66 suggests that the variety response to trashing needs to be considered. Rouillard (1963) found that breakage of cane stalks due to trashing was more important where yields are high and in cane having a tendency to lodge. As the varieties under test were mostly erect and the yields rarely exceeded 80-t ha⁻¹, this explains the negligible number of broken canes recorded.

The other causes examined were mechanical injury caused to the plant during trashing by removal of some partially green leaves still attached to the stem and emergence of more water-shoots and suckers after the early trashing. De Sornay (1936) reported that removal of green or partially dry leaves at trashing reduces the photosynthetic activity and may affect cane growth. This effect was confirmed in phase 2 trials although the absolute increase in cane growth was low. As cane growth usually slows down in May, the effect might have been more pronounced in March or April when cane is still growing actively. As the soft trashing also caused a reduction in cane growth, it can be deduced that other factors like the shock caused to the stalk and stool during trashing also contribute to this effect. The recovery observed in ST plots at Pamplemousses can be explained by greater photosynthetic activity due to the higher temperature and solar radiation than at Union Park. The penetration of light in the canopy and other physiological disturbance made to the plant by an early trashing induced emergence of more water-shoots and suckers; the development of these shoots may have occurred at the expense of cane growth (Shrivastava and Misra 1996).

It is possible that other factors than those evaluated above may also be responsible for the reduction in yield; the effects of trash on soil moisture and temperature after trashing need to be studied

CONCLUSION

Studies have shown that an early trashing may lead to a reduction in cane yield, confirming observations made in a previous trial. The possible causes identified are mechanical injury and shock suffered by the stalk due to removal of partially green leaves still attached to the stem, emergence of more water-shoots and suckers. Other causes may include the number of broken canes during trashing.

ACKNOWLEDGEMENTS

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IMPROVING USE OF LIMITED WATER BY SUGAR CANE

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ABSTRACT

A computer simulation approach was used to evaluate irrigation strategies that would improve the use of limited water supplies through optimum use of effective rainfall while meeting sugar cane water requirements. The results showed that for the site under study in nine out of ten seasons, strategies based on management allowable soil water deficit (MAD) threshold levels equivalent to 140% of Readily Available Water (RAW) used 200 mm water less than (MAD) levels equal to 100% RAW. There was little or no effect on the level of crop water satisfaction (ET_a / ET_c) between the two strategies. Irrigation doses corresponding to 60% replenishment of the root zone depletion at 7 day-interval required about 440 mm less water than irrigation doses needed for the complete replacement of the root zone depletion every 2 days. Such strategies however could lead to a maximum reduction of 13% in the crop water satisfaction level and could therefore have an impact on achievable yield. Although crop water use could be affected, the benefit of these irrigation strategies relied on substantial savings of water that could be used in other areas hitherto not irrigated because of insufficient water. Further field studies and financial analyses of the various strategies are needed.

Keywords: Sugarcane, *Saccharum officinarum*, water requirements, water use, irrigation, irrigation rates, simulation models, Mauritius.

INTRODUCTION

Sugar cane is grown in Mauritius on about 75 000 hectares, half of which requires irrigation. However, owing to insufficient water and increasing competition for water by non-agricultural users, about 18 000 hectares cannot be irrigated. This causes a shortfall in cane production of the order of 360 000 t based on a conservative incremental yield of 20 t ha⁻¹. Moreover, even in areas of the sugar industry with adequate water supply, production is sometimes limited due to lack of water during drought periods.

These issues, together with delays in the expansion of irrigated areas have caused increasing concern for a more judicious use of the existing irrigation supplies. Research has been initiated not only in Mauritius, but also in sugar cane growing areas of Australia and South Africa (Robertson et al 1997) and Brazil (Chaudhry and Leme 1996) to develop strategies that would optimise the use of limited water by the crop. New approaches for improving sugar cane yield through deficit irrigation practices (Anon 1997) and through optimisation of limited water allocation (Ah-Koon et al. 1997) have thus been introduced. Through deficit irrigation, which is a deliberate and systematic under-irrigation strategy (English and Raja 1996), the crop is allowed to sustain some degree of stress and yield reduction. Potential benefits of such irrigation practices have been shown to result in lower production costs and enhanced water-use efficiency (English and Raja 1996; Hoffman and Martin 1993).

The choice of a deficit irrigation practice depends mostly on the possibilities of harvesting effective rainfall, which according to Hershfield (1964), is that part of the seasonal rainfall that is available to meet the crop water requirement. Proper irrigation management that takes effective rainfall into consideration requires appropriate crop, soil moisture and rainfall databases. As irrigation management becomes more complex, computer programs are increasingly being used and have been found to be useful tools to generate solutions for different irrigation management problems (Mohan and Arumugam 1997). Computer simulation models for predicting sugar cane yield responses to irrigation (Inman-Bamber et al 1993) or combination of rainfed and irrigated sugar cane production (Wyseure et al 1994) are currently being used.

In Mauritius, with the forthcoming construction of the Midlands Dam and the rehabilitation of the existing irrigation pipe lines, there are indications that additional water supplies will be made available for the improvement and upgrading of existing schemes or for the implementation of new irrigation projects. Considering the high capital investment involved to provide these additional supplies, it is imperative that the water be used judiciously and crop water use be optimised. Any saving in the amount of water applied to the crop with little or no effects on achievable yields will undoubtedly contribute to greater economy and increased viability of sugar cane irrigation. The current study was therefore initiated to evaluate strategies that would improve the use of limited irrigation supplies through improved use of effective rainfall while satisfying sugar cane water requirement.

MATERIALS AND METHODS

A computer simulation approach was used to evaluate the effects of different irrigation practices on sugar cane crop water use over 39 consecutive years at Beau Séjour. Current estate practices and various degrees of deficit irrigation practices that could be applied by a centre pivot were compared. The centre pivot system was chosen not only because it is rapidly gaining importance in Mauritius (Teeluck 1998) but also for its versatility and its ability to apply different irrigation options. Ratoon crops were assumed to be irrigated between September and May and harvested in August every year. Seasonal actual evapotranspiration (ET_a) as well as irrigation required through different growing seasons for each irrigation strategy were calculated and ranked for probability analysis according to the method described by Doorenbos and Kassam (1979). For each irrigation strategy, the maximum amount of water required for the growing season and the corresponding minimum level of crop water satisfaction (ET_a / ET_c) that can be achieved nine out of ten years, were retained for comparison. The amount of water saved was then calculated for strategies that required less irrigation while maintaining crop water satisfaction at an acceptable level.

The irrigation scheduling software IRRIPIVO, developed for the centre pivot system (MSIRI 1996), was used for the exercise. The software, based on a soil water balance method and similar to that used by Hess (1996), required the following data input:

1. Rainfall
2. Reference crop evapotranspiration (ET_o)
3. Crop factor (kc)
4. Soil moisture holding capacity
5. Irrigation applied

Rainfall data

Thirty-nine years (1958 - 1996) of daily rainfall data from Beau Séjour were available and were used for this exercise. The site is 114 m above sea level and has a long term mean annual rainfall of 1550 mm (Padya 1984).

Rainfall was converted to effective rainfall (R_e) according to the following formula (Hershfield 1964):

$$R_e = 0.9 \times (R - 2) \leq \text{SMD} \quad (1)$$

Where, R: Rainfall,
and SMD: Soil moisture deficit

Reference crop evapotranspiration (ET_o)

As daily reference crop evapotranspiration (ET_o) data were not available for Beau Séjour, average monthly ET_o for the period 1961-1980 was taken from the representative nearby site of Pamplémousses (Padya 1984). Since the error in using historical reference evapotranspiration rather than real-time reference crop evapotranspiration is only about 14% or less (Hanson 1996), the substitution is quite acceptable for the present exercise.

Crop factor

The crop factors shown in Table 1 were derived from those defined by Doorenbos and Kassam (1979) and were used to estimate potential crop evapotranspiration (ET_c).

Table 1. Crop factors (kc) at different sugar cane growth stages

Crop age months	Growth stage	kc
0 - 1	harvest to 0.25 full canopy	0.40
1 - 2	0.25 - 0.5 full canopy	0.70
2 - 2.5	0.5 - 0.75 full canopy	0.95
2.5 - 4	0.75 to full canopy	1.10
4 - 10	full canopy	1.15
10 - 11	early senescence	0.85
11 - 12	ripening	0.65

Soil moisture holding capacity

The soil group at Beau Séjour is the free draining Latosolic Reddish Prairie (P2) of the Labourdonnais family (Parish and Feillafé 1965). The soil moisture holding capacity for an effective rooting depth of 45 cm was obtained from soil tests (MSIRI, unpublished) and was equivalent to 25.8 mm of Readily Available Water (RAW) and 40.9 mm of Total Available Water (TAW).

Simulated overhead irrigation

The amount of overhead irrigation water required was generated through computer simulation according to scenarios based on frequency, irrigation dose, and management allowable soil water deficit (MAD) as given below:

1. Irrigating at fixed interval of every 2 days, 4 days, 7 days, and 10 days.
2. Applying irrigation dose equivalent to a percentage of the soil moisture depletion of the root zone, e.g. an irrigation of 100% depletion to bring the soil moisture reservoir to field capacity. Irrigation doses selected were 100%, 80%, 60%, and 40% depletion.
3. Irrigating when the soil water deficit reached a MAD threshold level equivalent to a percentage of the readily available water (RAW). The MAD levels selected were 100%, 120% and 140% of RAW.

Combinations of strategies 1 and 2 and combinations of strategies 2 and 3 were analysed. In all strategies, no irrigation was applied whenever the net irrigation requirement was less than 10 mm, which corresponds to the minimum irrigation that can be applied daily by most centre pivots in Mauritius.

The relationship between net irrigation and gross irrigation was assumed to be similar to that between total rainfall and effective rainfall:

$$Irr_{net} = 0.9 \cdot (Irr_{gross} - 2) \quad (2)$$

Potential crop evapotranspiration (ETc)

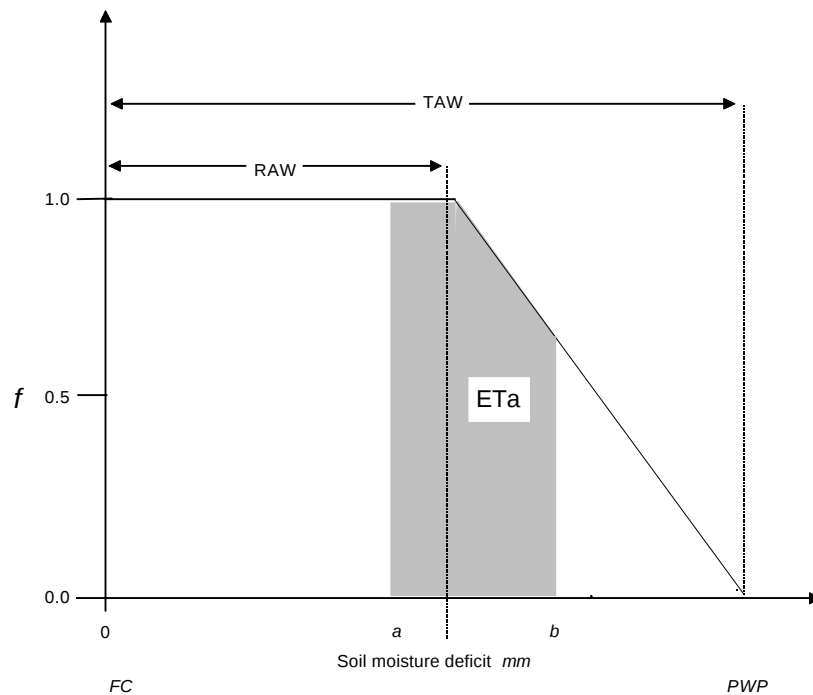
The potential crop evapotranspiration (ETc) for a healthy crop not short of water was obtained by multiplying the reference crop evapotranspiration (ETo) by the appropriate crop factor (kc) according to the equation given by Doorenbos and Kassam (1979):

$$ETc = ETo \cdot kc \quad (3)$$

Actual evapotranspiration (ETa) model

The actual evapotranspiration (ETa) model is based on the assumption that, as long as the soil water content is within the readily available range, the cane would not be stressed and would therefore be evapotranspiring at its potential rate (ETc). When soil moisture deficit (SMD) is beyond the range of readily available water (RAW) but within that of the total available water (TAW), ETa would be less than ETc. Finally if SMD is beyond the TAW range, the crop is considered to be under complete stress and ETa = 0. The model used to estimate ETa is illustrated in **Figure 1** and is similar to that derived by Rijtema and Aboukhaled (1975).

Figure 1. Calculation of actual Evapotranspiration (ETa)



ETa, Which is represented by the shaded areas, derived from the following equation:

$$ETa = \int_a^b f \cdot dx \quad f = \begin{cases} 1 & \text{SMD} < \text{RAW} \\ 1 - \left(\frac{\text{SMD} - \text{RAW}}{\text{TAW} - \text{RAW}} \right) & \text{RAW} \leq \text{SMD} < \text{TAW} \\ 0 & \text{SMD} \geq \text{TAW} \end{cases}$$

Where,

x = Soil moisture deficit (SMD)

a = SMD_n

b = SMD_n + ETc_n

SMD_n = Soil moisture deficit on day n

ETc_n = Potential evapotranspiration on day n

Validation of ETa model

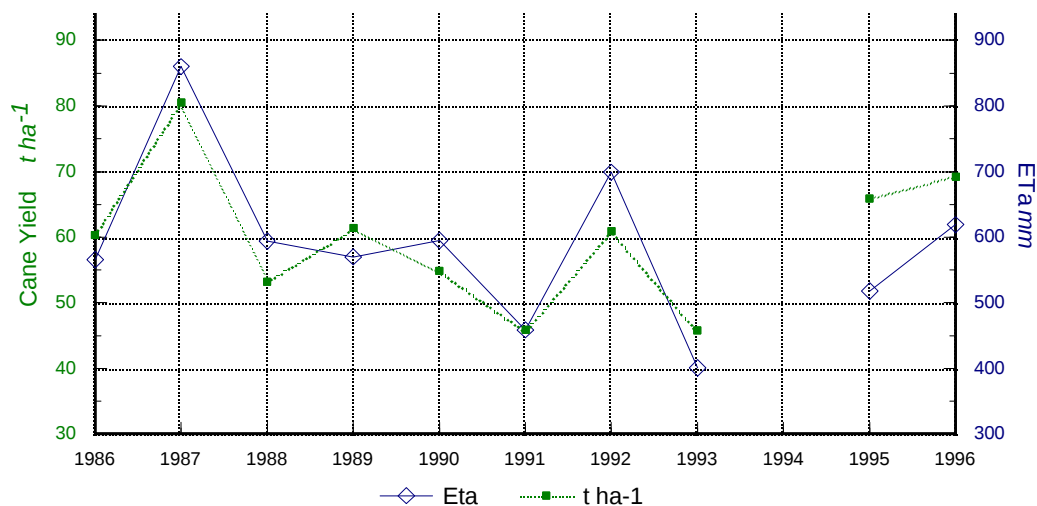
The ETa model was validated using long term climate and sugar cane yield data from another site (Bassin) which is at an altitude of 314 m and with a mean annual rainfall of 1250 mm (Padya 1984). The soil group is the Latosolic Reddish Prairie (P1) of the Médine family (Parish and Feillafé 1965). Readily Available Water and Total Available Water, for an effective rooting depth of 45 cm, are 38.2 mm and 48.4 mm respectively. Seasonal ETa values generated from the model were compared with rainfed sugarcane yields for 10 crop cycles.

RESULTS AND DISCUSSION

Validation results

The close agreement between cumulated ETa and the cane yield as shown in Figure 2 demonstrates that the temporal variation of seasonal ETa values and achievable yield follow the same trend. The calculated ETa from the model appears to be a good indicator of achievable yields and it can therefore be assumed that the model is valid for the type of computer simulation experiments reported in this study. The validation exercise however, does not give an actual relationship between achievable yield and water use and as such cannot predict the achievable yield of each irrigation strategy. To assess the different strategies, the ratio ETa/ETc was used instead. This ratio, which combines effective rainfall and effective irrigation, provides an indication of the level of crop water satisfaction. Furthermore, probability analysis of the ETa / ETc ratio, as opposed to probability analysis of rainfall only, offers the advantage of reducing complexities associated with rainfall distribution and other difficulties related to the conjunctive use of rainfall and irrigation.

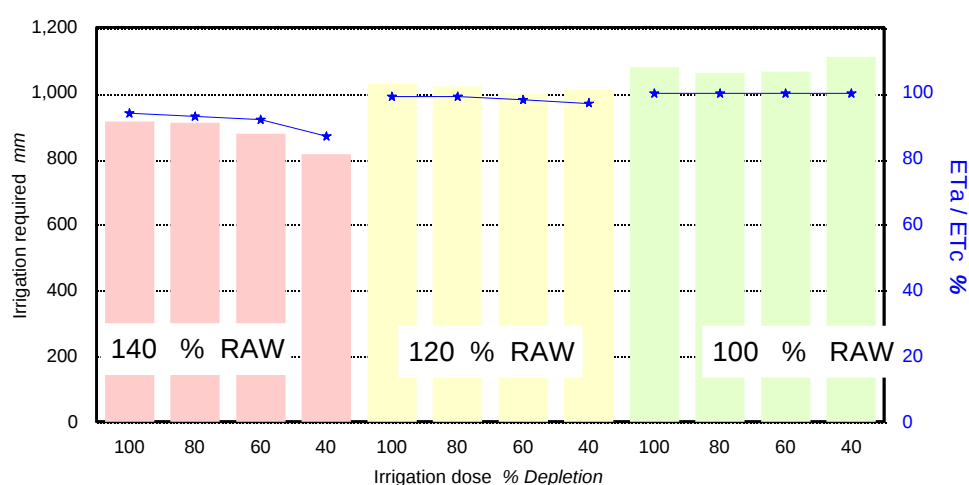
Figure 2. Calculated actual evapotranspiration and sugar cane yield under rainfed condition at Bassin.



Strategies based on MAD and irrigation doses

The maximum amount of irrigation that would be needed and the corresponding levels of crop water satisfaction (ETa/ETc) that could be achieved 9 out of 10 years for the different strategies are shown in Figure 3 and Table 2. For the site under study, the levels of crop water satisfaction were greater than 95% for most of the combinations of MAD and irrigation doses Figure 3. The exception was for MAD level corresponding to 140% RAW for which the crop water satisfaction decreased from 94% to 88% with decreasing irrigation doses. No real differences in irrigation required could be observed between the different irrigation doses within the same MAD threshold level. However the results show that there is a definite trend for applying less water with MAD levels set to 140% RAW. These results are in close agreement with those reported by Jones and Richtie (1990) for different irrigation threshold levels and irrigation control of soya bean and maize.

Figure 3. Effects of 3 different MAD options on the amount of irrigation required and crop water satisfaction (ETa / ETc) at Beau Séjour



The difference in the amount of effective rainfall used between the rainfed treatment and the wettest strategy (i.e., the irrigation strategy that requires most water), gives an idea of the amount of rainfall that would be “wasted” should this wettest strategy be adopted **Table 2**. On the other hand if the strategy is to irrigate at MAD of 140% and dose equivalent to 60% depletion, then 375 mm out of the available 398 mm effective rainfall would be used thus enabling a saving of up to 19% or 203 mm compared to the wettest strategy.

Table 2. Amount of irrigation saved with MAD strategies at Beau Séjour.

Strategy		Effective rainfall	Irrigation required	ETa / ETc	Water saved	
MAD	Dose					
% RAW	% depl.	mm	mm	%	mm	%
100	100	292	1 080	100	-	-
100	80	314	1 062	100	18	2
120	100	353	1 029	99	51	5
120	60	375	998	98	82	8
140	100	338	914	94	166	15
140	60	375	877	92	203	19
Rainfed		398	0	34	1 080	100

The contribution of effective rainfall in reducing the amount of irrigation water would be about 80 mm out of the total 203 mm saved. This suggests that the amount of water saved, not attributed to effective rainfall, comes therefore from the deliberate under-irrigation of the crop thereby decreasing the crop water satisfaction by about 8%.

Further, the need for irrigation during the period under study can be demonstrated by the low level of crop water satisfaction (34%) for rainfed sugarcane at Beau Séjour. Overall, the results suggest that in order to optimise a limited irrigation supply at Beau Séjour, the most likely strategy to be adopted is to irrigate at MAD of 140% RAW and dose equivalent to 60% depletion.

Strategies based on irrigation frequencies and irrigation doses

The results that could be achieved 9 out of 10 years for the strategies based on the various combinations of irrigation frequencies and doses are illustrated in Table 3 and Figure 4. Regardless of irrigation doses, the level of crop water satisfaction decreases when the irrigation interval reaches 7 days and beyond. Also, less water is required with increasing irrigation intervals and decreasing application doses. **Figure 4**

Figure 4. Variation of irrigation required and crop water satisfaction (ETa / ETc) with different irrigation frequencies and doses at Beau Séjour.

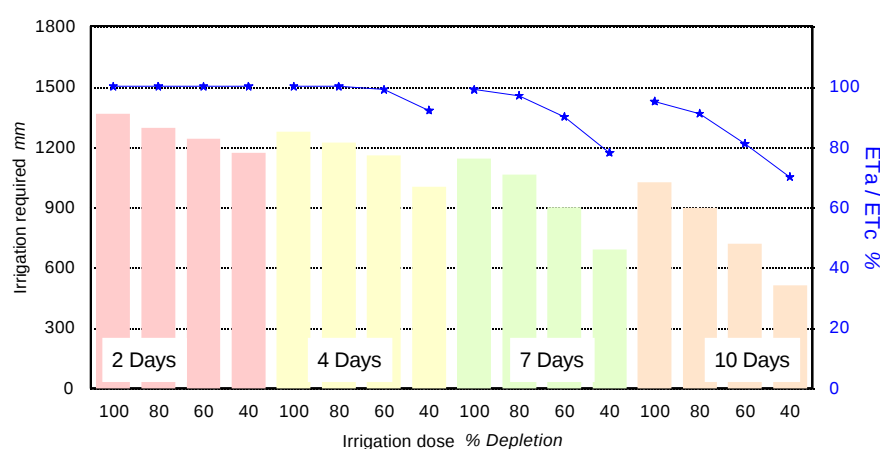


Table 3 gives a summary of the strategies that result in water savings with respect to the more intensive strategy (2 days interval and 100% depletion). The difference of 162 mm between the rainfall use of the rainfed cane and the more intensive irrigation strategy gives an indication of the potential amount of effective rainfall that can be harvested. Overall, the results show that the most likely irrigation strategy that would optimise the use of a limited water supply appears to be the 7-day irrigation interval in which, depending on the irrigation dose to be adopted, 13 to 34% of irrigation water can be saved. The strategy that results in maximum water saving is the 7-day irrigation interval and irrigation dose of 60% depletion, whereby up to 34% or 437 mm can be saved (compared to the most intensive irrigation strategy). This strategy, however, entails a reduction in crop water satisfaction of the order of 13%.

Fixed irrigation interval versus variable irrigation interval (MAD)

A comparison of the results presented in **Tables 2** and **3** reveals that the strategies based on the management of the soil moisture deficit systematically require less irrigation than the scenarios based on irrigation frequencies and irrigation doses. The strategy of irrigating every 2 days with doses equivalent to 100% depletion makes use of the least amount of effective rainfall (only 236 mm out of the potential 398 mm) **Table 3**. Comparing scenarios of the two methods that result in maximum water saving, there is no significant difference in the amount of irrigation water required for the two methods. However, when comparing strategies of the two methods that require similar irrigation amounts, the MAD strategies appear to result in higher levels of crop water satisfaction.

Table 3. Amount of irrigation saved with strategies based on irrigation frequencies and doses at Beau Séjour.

Strategy		Effective rainfall	Irrigation required	ETa / ETc	Water saved	
Frequency	Dose					
<i>days</i>	<i>% depl.</i>	<i>mm</i>	<i>mm</i>	<i>%</i>	<i>mm</i>	<i>%</i>
2	100	236	1 273	100	-	-
2	60	299	1 220	100	53	4
2	40	353	1 155	100	118	9
4	100	244	1 203	100	70	5
4	60	331	1 088	100	185	14
4	40	361	953	93	319	25
7	100	288	1 108	100	165	13
7	80	327	999	97	274	22
7	60	359	836	87	437	34
10	100	307	965	93	307	24
10	80	344	849	89	424	33
Rainfed		398	0	34	1 273	100

CONCLUSIONS

The use of computer simulation and actual evapotranspiration models appear to be helpful tools to assess the effects of different irrigation practices on crop water use. In the current study, the irrigation scheduling software IRRIPVO was used to simulate deficit irrigation strategies that could improve the use of limited water supply while maintaining sugar cane water requirement at a satisfying level. Important water saving of up to 200 mm can be achieved through the use of strategies based on Management Allowable soil water Deficit (MAD) with little effects on crop water satisfaction. On the other hand, strategies based on fixed irrigation interval show that up to 440 mm of water could be saved for an expected reduction in crop water satisfaction of about 13%. Comparison of the MAD and fixed irrigation methods shows that for strategies that required similar irrigation amounts, the MAD strategies appear to result in higher levels of crop water satisfaction. Although some of the strategies result in reductions of crop water satisfaction (and possibly affect achievable yields), the benefits that could be derived from such strategies rest on the water savings that can then be used in other areas hitherto not irrigated because of insufficient irrigation water. It is therefore necessary to verify the above findings through real-life experimentation and also to combine agronomic results with economic factors to compare profitability and risks associated with each irrigation strategy.

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POTASSIUM LEACHING IN SOILS UNDER RAINFED SUGAR CANE IN MAURITIUS

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ABSTRACT

Leaching losses of potassium (K) in freely drained soils under sugar cane were followed in field lysimeters over a 3-year period at 2 sites receiving 3 700 and 1 550 mm rainfall yr⁻¹, respectively. As little K (<5kg K ha⁻¹ yr⁻¹) was lost by leaching, split application of K fertilizers would be superfluous even in the high rainfall regions of Mauritius. However, fertilizer K application even at 140 kg K₂O ha⁻¹ significantly enhanced leaching of calcium (Ca) and magnesium (Mg) from soils.

Keywords: potassium, calcium, magnesium, leaching, sugar cane, *Saccharum officinarum*, rain fed farming, Mauritius.

INTRODUCTION

Increasing costs of fertilizers, and concern with water quality have motivated interest to minimize losses and to improve the efficiency use of fertilizers. Soils of Mauritius have low cation exchange capacity (Anon 1988) and hence have only a limited capacity to retain the major plant nutrient cations such as Ca, Mg and K. This low cation exchange capacity (CEC) coupled with the high rainfall often encountered in Mauritius could be conducive to an extensive leaching of the nutrient cations. Indeed, as reviewed by Pieri and Oliver (1986), the risk of leaching losses of K under humid tropical conditions is very high, especially when generous rates of K fertilizers are applied on freely drained soils of low CEC. However, although significant leaching losses of fertilizer nutrient cations may be expected in the highly permeable low CEC soils of the humid tropics, published data on the magnitude of leaching are scanty. Yet such information is of fundamental importance in the development of more productive soil and crop management systems to prevent the wastage of costly fertilizers. The study reported in this paper was therefore initiated with the objectives of evaluating the significance of fertilizer K leaching losses in soils under sugar cane in Mauritius and the effect of split K application on these losses.

MATERIALS AND METHODS

The studies were performed in concrete lysimeters (2 m long by 1.5 m wide by 1 m deep) at 2 sites, namely Réduit and Belle Rive. Although they do not resemble field soils in every aspect, lysimeters are ideal for studying nutrient movement from agricultural soils because leachate is easily collected and can be accurately analysed (Shepherd and Bennett 1998). Réduit is located in a geographical region with an average annual rainfall of 1 550 mm while Belle Rive has a mean annual rainfall of 3 700 mm. Most (70%) of the rainfall at the 2 experimental sites is generally received between December and April.

The Low Humic Latosol (LHL) soil at Réduit and the Humic Ferruginous Latosol (HFL) soil at Belle Rive were carefully removed from the field, horizon by horizon and similarly packed into 6 lysimeters at each site. The characteristics of the 2 soils are given in Table 1. The soil in the lysimeters was allowed to settle for 10 years before sugar cane (varieties R 570 at Réduit and M 3035/66 at Belle Rive) was planted in a single row 2 metres long in the middle of each lysimeter.

Table 1 Characteristics of the soils* at Belle Rive and Réduit

Parameter	Site	Soil depth <i>cm</i>					
		0-15	15-30	30-45	45-60	60-75	75-90
Organic matter %	Belle Rive	4.9	3.1	2.7	1.0	0.8	0.9
	Réduit	3.3	1.8	1.2	0.7	0.5	0.4
CEC <i>c mol kg⁻¹</i>	Belle Rive	7.9	2.2	0.9	0.3	0.3	0.3
	Réduit	5.1	4.3	4.7	5.2	5.6	6.0
Exchangeable Ca <i>c mole kg⁻¹</i>	Belle Rive	7.1	1.9	0.7	0.2	0.2	0.2
	Réduit	3.1	2.6	3.0	3.2	3.1	2.9
Exchangeable Mg <i>c mole kg⁻¹</i>	Belle Rive	0.6	0.2	0.1	0.0	0.1	0.0
	Réduit	0.8	0.8	0.8	0.8	0.8	0.9
Exchangeable K <i>c mole kg⁻¹</i>	Belle Rive	0.1	0.1	0.1	0.1	0.1	0.1
	Réduit	0.7	0.2	0.1	0.1	0.1	0.1
Sand %	Belle Rive	37.9	40.6	41.6	51.6	54.3	61.8
	Réduit	7.5	5.6	7.3	18.4	27.4	31.2
Silt %	Belle Rive	26.7	29.0	32.8	29.4	30.2	25.6
	Réduit	15.1	10.2	10.6	16.4	20.5	22.6
Clay %	Belle Rive	35.4	30.4	25.6	18.0	15.5	12.6
	Réduit	77.1	84.1	82.1	65.2	52.1	45.9

* for complete description, see Parish and Feillafé (1965)

The following 3 treatments in duplicate were applied yearly in November to the sugar cane in the lysimeters:

1. Control (no K applied).
2. 240 kg KCl ha⁻¹ applied in a single dose at planting or just after harvest of preceding sugar cane crop.
3. 240 kg KCl ha⁻¹ applied in 2 equal split doses at planting or just after harvest of preceding sugar cane crop and eight weeks later.

Adequate nitrogen (600 kg ammonium sulphate ha⁻¹), phosphorus (50 kg triple super phosphate ha⁻¹) and silicon (1.5 t ha⁻¹ calcium silicate at planting in the soil of Belle Rive only) were also applied to the sugar cane in the lysimeters. At the end of a study period of 2 years, the rate of KCl in treatment 3 was increased to 480 kg ha⁻¹.

Rain water collected 1.5 m above ground level at each site and leachates percolating by gravity at 1 m soil depth after every rainfall event were analysed for K by flame photometry and for Ca and Mg by atomic absorption spectrophotometry Table 2. The sugar cane plants in each lysimeter were cut just above the soil surface in November.

Table 2. Yearly input of Ca, Mg and K (*kg ha⁻¹*) from rainfall at Réduit and Belle Rive

Year	Belle Rive				Réduit			
	Rainfall <i>mm</i>	Ca	Mg	K	Rainfall <i>mm</i>	Ca	Mg	K
1	2 436	12.9	14.4	9.7	696	4.2	6.1	3.2
2	2 968	17.4	11.1	8.8	1 176	6.3	4.4	3.6
3	3 112	15.9	13.0	17.5	1 193	8.7	4.5	5.8

RESULTS AND DISCUSSION

Soil cation leaching under field conditions has been defined as the movement of the cation beyond the plant root zone (Huete and McColl 1984). On the basis of this definition of cation leaching, the data obtained over a 3-year study period showed that leaching losses of K from soils in Mauritius would be low ($< 5 \text{ kg K ha}^{-1} \text{ yr}^{-1}$) irrespective of location or climatic conditions (Table 3).

Table 3. Influence of K rates on leaching losses of Ca, K and Mg from soils in lysimeters planted with sugar cane

Treatment	Site	$\text{kg ha}^{-1} \text{ yr}^{-1}$		
		Ca	K	Mg
0 $\text{kg K}_2\text{O ha}^{-1}$ Control ***	Belle Rive	342	4	15
	Réduit	216	4	24
140 $\text{kg K}_2\text{O ha}^{-1}$ in one dose ***	Belle Rive	408	4	19
	Réduit	241	4	30
140 $\text{kg K}_2\text{O ha}^{-1}$ in 2 equal doses **	Belle Rive	397	3	18
	Réduit	193	5	35
280 $\text{kg K}_2\text{O ha}^{-1}$ in one dose *	Belle Rive	490	4	18
	Réduit	358	8	62
SE $\pm$		71.9	0.6	2.3

Belle Rive variety M3035/66 Réduit variety R 570.

*** mean of 3 years

** mean of 2 years

* One year data

On average even when the K was applied in a single dressing in the high rainfall region of Belle Rive, less than 1% of the fertilizer K would move beyond the 1 m soil depth. That small amount of K loss by leaching was compensated by the K input from rainfall (Table 2&3). The agronomically insignificant leaching of K from soils which has also been observed elsewhere, e.g. in Nigeria, reflected the strong affinity of tropical soils for this monovalent cation when the degree of K saturation of the exchange complex is small (Wong et al 1992).

The negligible leaching loss of fertilizer K confirms that the practice of split K application to improve the efficiency of K fertilizers in the high rainfall region of Mauritius would be superfluous. In fact, Ng Kee Kwong et al (1994) had already demonstrated that split K application in soils where annual rainfall exceeds 3 000 mm yr^{-1} did not improve the yield and the K nutritional status of sugar cane. Furthermore with the mineralogy of soils in Mauritius dominated by either oxides of iron and aluminum or kandites, little of the K applied would be fixed by the soils (Anon 1982). Consequently the behaviour or fate of K fertilizers in soils of Mauritius is therefore quite simple; namely the K fertilizer if not taken up by the current sugar cane crop will stay available in soils for use by subsequent crops unless it becomes positionally inaccessible to the roots.

The data obtained in the present study highlighted the extensive leaching losses of calcium and magnesium from the soils in Mauritius. As shown in Table 3, more than 300 kg Ca $\text{ha}^{-1} \text{ yr}^{-1}$ were lost annually by leaching at Belle Rive ($>200 \text{ kg Ca ha}^{-1} \text{ yr}^{-1}$ in the drier area at Réduit). Extensive losses of Ca and Mg from the soils in the humid tropics have also been observed elsewhere (see eg Cahn et al 1993). Indeed, Wong et al (1992) found Ca to be the element leached in greatest quantity from soils in Nigeria, the average total for 2 years being 312 kg Ca $\text{ha}^{-1} \text{ yr}^{-1}$.

The application of K fertilizers to soils accelerated the leaching of Ca and Mg (Table 3). The enhanced leaching of Ca and Mg as a result of K fertilization has been attributed to the fact that K in competing with Ca and Mg for the cation retention sites displaces the Ca and Mg into the soil solutions (Neilsen and Stevenson 1983). In this context, Poss and Saragoni (1992) showed that the K concentration in soil solution in Togo decreased rapidly after addition of K fertilizer and remained low by displacing the Ca and Mg ions on the exchange sites.

CONCLUSION

The present study shows that fertilizer K when used judiciously is not subject to leaching loss irrespective of the rainfall regime and of the use pattern (application in one or split doses). Excessive use of K fertilizers in sugar cane, for example 240 kg K₂O ha⁻¹, should be avoided not to minimize leaching of K but rather to attenuate losses of cations such as Mg and Ca from the soil. Furthermore, in view of the negligible K leached, amendment or practice with the specific aim of improving K retention in soils is superfluous. Instead to stop the degradation of the soils and development of acidity, amendments must on the contrary be aimed at replacing the Ca and Mg leached from the soils. Without these amendments, the fertility of the agrosystems in Mauritius cannot be sustainable in the long term.

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EFFECT OF DIFFERENT LEVELS OF NITROGEN ON YIELD AND QUALITY OF PINEAPPLE VARIETY QUEEN VICTORIA

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ABSTRACT

The relationship between level of nitrogen fertiliser, and the yield and quality of pineapple fruits (cv. Queen Victoria) was studied. The statistical design was a simple randomised block of seven treatments with four replicates. Prior to artificial flower induction, seven different rates of a nitrogen fertiliser (urea at 0, 140, 280, 420, 560, 700, 840 kg N ha⁻¹) were applied in seven equal split doses. As the level of nitrogen fertiliser was increased, a decrease in acidity of fruits and an increase in crown weight were observed. However, an increase in mean length of D leaf, mean fruit length, mean fruit weight, mean fruit to crown ratio and mean percentage infection of fruit core rot were obtained, as the rate of nitrogen fertiliser was increased from 0 to 420 kg N ha⁻¹. Further increase however led to a decrease in the same parameters.

Keywords: pineapples, *ananas comosus*, fertiliser application, nitrogen, split dressings, fruiting, fruit quality, Mauritius

INTRODUCTION

In order to realise its growth potential; the pineapple plant need a sufficient supply of necessary elements. The most important of these elements is nitrogen. Plant growth depends mainly on nitrogen nutrition and the nitrogen balance (Martin-Prevel 1959e). There is a constant depletion in amount of available nitrogen in the soil through absorption by plants, fixation in the soil, leaching and volatilisation, the mineral element at the plants' disposal must be restored. Fertilisation plays a very important role in crop management. Nitrogen requirements are more beneficial if they are applied during leaf growth, i.e. before the appearance of the inflorescence. Under these conditions, supplies will have little negative effect on fruit quality. This study aimed at investigating the effect of different rate of nitrogen fertiliser urea on yield and quality of pineapple fruits.

MATERIALS AND METHODS

The experiment was conducted in August 96 on variety Queen Victoria at Belle Vue Allendy, Constance Sugar Estate. Suckers of uniform size (200 - 250g) taken from the base of the mother plant were used as planting material. These were planted in three rows at a spacing of (20 x 30-x 30 x 90 cm) and the cultural practices were maintained as for commercial crops. The statistical design was a simple randomised block of seven treatments with four replicates. The plot size was 252 m² with 3 rows of 20 plants and 5 row plants on each side as border. The treatments included seven different level of nitrogen fertiliser, urea: 0, 140, 280, 420, 560, 700 and 840 kg N ha⁻¹. Simultaneously sulphate of potash at the rate of 577-kg K₂O ha⁻¹ was uniformly applied to each plot. Fertilisers were applied in liquid form with a knap sack sprayer 7 occasions at intervals of 35, 30, 30, 30, 25, 25, 20 days. The induction treatment was applied fifteen days after the last fertiliser application in March 97. Ethrel at the rate of 3 litres ha⁻¹ and 50 kg of urea in 2000 litres of water were sprayed on the whole foliage including the rosette with a knap-sack sprayer.

Prior to the flower induction treatment, a random sample of the D-leaf of 5 plants from each plot was collected to determine the level of N, P and K. The total yield was recorded for each plot and a random sample of 20 fruits was taken to assess the fruit quality. The parameters observed were fruit weight and

length, crown weight and length, fruit diameter, fruit to crown ratio, extent of infection of Fruit Core Rot (FCR), Brix %, and degree of acidity.

RESULTS

Uniform flowering was noted in the pineapple plants 36 days after the flower induction treatment. Fruits were harvested as from the beginning of September 97 over a period of 29 days over 7 occasions (on the 2nd, 9th, 11th, 16th, 17th, 23rd and the 30th of September 97).

Results are given in **Tables 1, 2** and **3**

Table 1 . Analysis of D-leaf prior to flower induction treatment.

N level <i>Kg ha⁻¹</i>	Mean length <i>cm</i>	Mean width <i>cm</i>	Mean weight <i>gm</i>	Mean N <i>%</i>	Mean P <i>%</i>	Mean K <i>%</i>
0	80a	3.8	45	0.8	0.16	2.8
140	81a	4.1	48	1.2	0.17	2.7
280	81a	3.9	47	1.2	0.17	2.3
420	81a	3.7	48	1.3	0.17	2.4
560	80a	3.7	45	1.5	0.16	2.6
700	74b	3.6	39	1.4	0.15	2.8
840	73b	3.8	41	1.3	0.16	2.5
SE $\pm$	1.8	0.2	3.2	0.2	0.01	0.2
	*	NS	NS	NS	NS	NS

SE: $\pm$ Standard error of individual means NS : Not Significant.

* : Means accompanied by different letters are significantly different at 95 % probability level

Table 2. Analysis of fruits

N level <i>Kg ha⁻¹</i>	Mean yield <i>Ton ha⁻¹</i>	Mean Fruit to Crown ratio	Mean Brix <i>%</i>	Mean acidity <i>meq %</i>	Mean FCR infection <i>%</i>
0	68	7.5 ab	15.8	15.4 a	4.8 c
140	78	7.8 ab	15.8	14.7 a	7.0 bc
280	83	7.6ab	16.0	13.9 bc	7.7 bc
420	85	8.6 a	15.1	12.0 d	11.4 a
560	80	7.5 ab	15.6	12.5 cd	10.1 ab
700	75	6.9 bc	15.8	12.4 d	7.5 bc
840	73	5.6 c	15.7	12.2 d	6.9 bc
SE $\pm$	3.9	0.45	0.33	0.48	1.1
	NS	*	NS	*	*

SE: Standard error of individual means NS : Not Significant

* : Means accompanied by different letters in a column are significantly different at 95 % probability level

Table 3. Analysis of fruits

Nitrogen <i>Kg ha⁻¹</i>	Mean Crown		Mean Fruit		
	Length <i>cm</i>	Weight <i>g</i>	Length <i>cm</i>	Weight <i>g</i>	Diameter <i>cm</i>
0	16.0	87 c	14.9 c	647 b	10.1
140	17.5	101 c	16.7 ab	783 a	10.6
280	17.4	111 b	16.8 ab	835 a	10.9
420	17.6	100 c	17.3 a	848 a	10.7
560	17.5	110 b	16.3 ab	813 a	10.4
700	17.8	111 b	15.7 bc	765 b	10.4
840	18.7	136 a	15.3 c	762 b	10.4
SE $\pm$	0.57	6.1	0.43	37.6	0.4
	NS	*	*	*	NS

SE: $\pm$ Standard error of individual means NS : Not Significant

*: Means accompanied by different letters in a column are significantly different at 95 % probability level.

DISCUSSION

Growth parameters of the leaf (length, width, and fresh weight) react differently to varying level of nitrogen fertiliser. Increasing the rate of nitrogen had a significant effect on the length of the D-leaf but no significant effect on its width, weight and foliar level of nitrogen, potassium and phosphorus.

Sideris and Krauss (1936) defined D-leaves as the longest leaves. Analysis of D-leaf is used to estimate growth, as it is the only leaf that can easily be identified and provides a reliable and sensitive indication of plant nutritional status. An unsatisfactory nutritional status at flower induction can cause a reduction in the weight of the fruit as compared to that of the vegetative organs, and elongation of the peduncle. The level of nitrogen fertilisers has a significant effect on crown weight, fruit length and weight, fruit to crown ratio and percentage infection of fruit core rot (**Figure 1**). An increase in average crown weight, average fruit length and weight, average fruit to crown ratio and average percentage infection of fruit core rot was obtained, as the rate of nitrogen fertiliser was increased to 420 kg N ha⁻¹. Further increase in the rate resulted in a negative effect on the above parameters. High nitrogen levels are detrimental to fruit quality. The diameters of the core and the peduncle increase with the supply of nitrogen. According to Py and Tisseau (1965), the length of the peduncle increases the risk of lodging and consequently of sunburn. High rate of nitrogen also increases the fragility and translucence of the fruit. A reduction in total soluble solids has also occasionally been noted (Montenegro et al. 1967; Abutiate and Eyeson 1973; Singh et al. 1977).

In this trial a decrease in acidity was noted with an increase in the rate of nitrogen. **Figure 2**. The most marked effect of an increase in nitrogen on fruit quality is a reduction in free acids as quoted by several authors (Cannon 1957, Py et al 1957, Dodson 1968, Gaillard 1970, Lacoeyille 1973, Singh et al 1977, Kwong et al 1966, Marchal et al 1980). The concentration of acids must be within certain limits (12.0 to 12.5 meq %). Low acid level implies the flavour will be insipid and there will be little aroma. High level reduces the sensation of sweetness and gives the fruit an unpleasant taste.

Figure 1. Effect of Nitrogen on fruit weight and crown weight

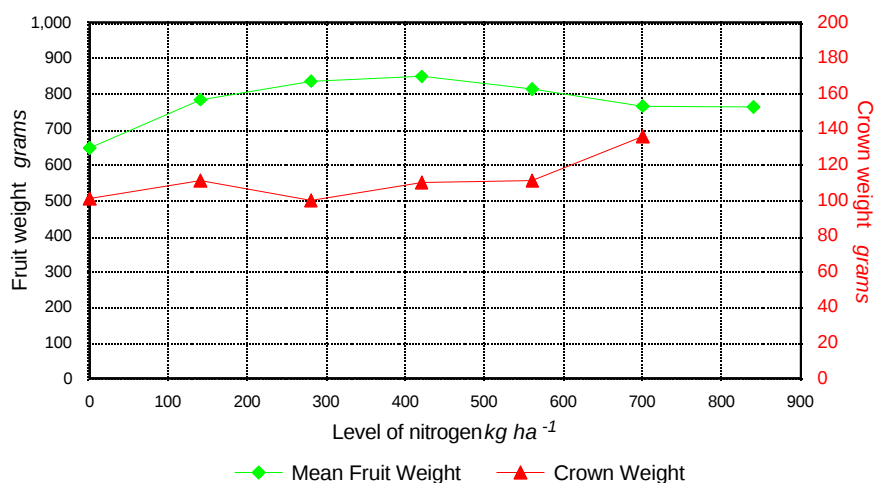
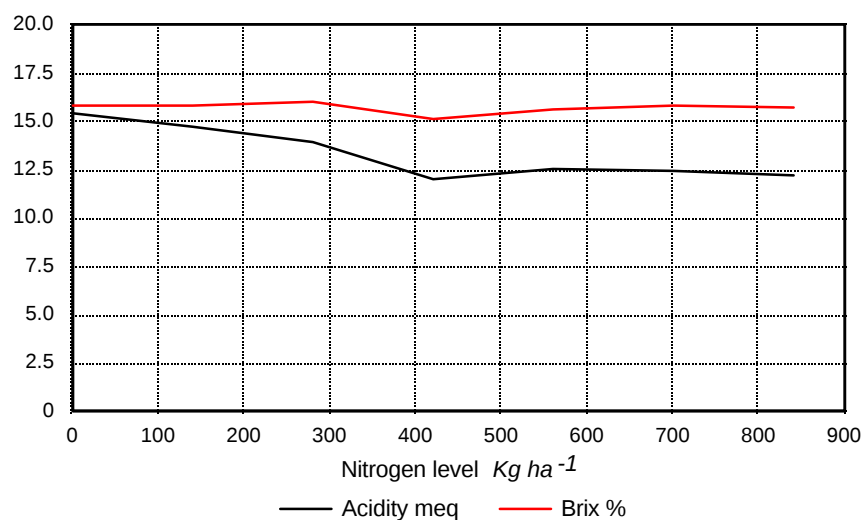


Figure 2 Effect of Nitrogen level on acidity and brix



CONCLUSION

Nitrogen nutrition is one of the main factors that determines plant growth and fruit weight of the pineapple. However, it has a marked effect on fruit quality. Nitrogen fertilisation is essential, but it should be effected with care with respect to dosage and stage in the cultivation cycle. In fact the dosage should be less than 420 kg N ha^{-1} . Nitrogen application is more beneficial when applied during leaf growth, i.e. before the appearance of inflorescence. The final dressing of fertiliser just before flower induction is extremely important (Lacoeuilhe 1978). The last fertiliser application should be effected 15 days prior to flower induction treatment. Under these conditions, supplies will have little negative impact on fruit quality.

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NUTRIENT CYCLING IN FOREST ECOSYSTEMS IN MAURITIUS: RATE OF NITRIFICATION

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ABSTRACT

Nitrification rate in the same soil type was studied by the in-situ sequential coring technique for two forest ecosystems. Nitrate production was not found to be linear over the 12-month period of observation, and was positively correlated with temperature. Significant differences in nitrification rates, organic matter and total nitrogen were observed in the two sites. The earthworm populations in the two ecosystems were also significantly different. These results suggest that nutrient cycling, especially nitrogen mineralisation, is more intense in an undisturbed system than in a forest ecosystem, and has implications for the development of any agroforestry system.

Keywords : cycling, ammonium fixation, nitrification, mineralisation, ecosystems, forest, earthworms, soil temperature, Mauritius

INTRODUCTION

Nitrification is a major regulator of nitrogen retention in forests (Montagnini and Sancho 1994; Vitousek and Matson 1987). The key to the survival of plant species in forest communities lies mostly in the efficient nutrient cycling carried out by autotrophic organisms (Chandler 1984). In forest ecosystems nitrogen losses are small because mineralisation occurs in synchrony with plant uptake (Lensi et al. 1992). In fact, Nadelhoffer et al (1984) have shown that rates of nitrogen mineralisation can regulate productivity of forest communities. The evergreen nature of most forest canopies is essentially due to nutrient recycling. On successional development of natural ecosystems, nutrients are increasingly transferred from mineral soils to plant biomass. Diversity of plant species generates temporal as well as spatial variation in rates of nutrient supply from decomposing organic matter (Heal and Harrison 1990). In agroforestry and in managed forest ecosystems, such as pine forests, manipulation of the soil and input of organic or inorganic fertilisers are meant to enhance nutrient supply to a single species with more or less an even age distribution, and with nutrient removal at harvest.

The present work is a comparative study of the mineralisation rates in a natural undisturbed ecosystem and a managed pine forest ecosystem, and is the first study of its kind in Mauritius.

The results may be applied to calculate nitrogen budget in any future agroforestry practices in these regions. Earthworm populations, which interfere in the mineralisation rates through its influence on denitrification, and have important effects on soil physical structure and fertility, have also been estimated for the two ecosystems.

MATERIALS AND METHODS

Study area

This study was conducted on a State forestland, adjoining a nature reserve area at Perrier near Mare aux Vacoas, at an altitude of 550 m and having a mean annual precipitation of about 3000 mm. The soil in this area is classified as Latosolic Brown Forest Soil (USDA: Lithic Humotropept; FAO: Dystric Cambisol) developed on the central late lava plateau. The soil is shallow, gravelly and is a dark brown, silty clay loam. For the purpose of this study, one site of 10 X 10 m was chosen from each ecosystem. Selection of these sites was made on the basis of vegetation and soil parameters to ensure that they were representative plots of the total catchment.

Methodology

The studies were restricted to the topsoil (0-15cm depth) where the organic matter, fine roots and earthworms are more concentrated. PVC pipes of 15-cm length and 5 cm, with 10 perforations of about 5 mm each along the length, were used as sampling cores. The perforations allowed aeration during the incubation period. Initially 30 such cores were inserted randomly in each of the two sites up to the full depth. Ten of these cores were removed immediately (time t) from each site and the various parameters analysed. Ten of the cores were covered with polythene sheet to prevent leaching and the other 10 were left uncovered. All 20 cores were left in the soil for an incubation period of 30 days (time t +1), after which they were removed to the laboratory for analyses of the various parameters. This was repeated every month for 12 months, from March to February of the following year. Parameters analysed in the laboratory were pH, total N, organic matter, mineral nitrogen (ammoniacal and nitrate), as per the methods outlined by Cottenie (1980). The differences in ammonium nitrogen and nitrate nitrogen concentration of the incubated samples and the fresh samples were considered to have been caused by ammonification and nitrification respectively during the 1-month incubation period. This paper reports data for the uncovered cores only. Earthworm populations were estimated using 1 m² quadrates in both sites at the beginning of the experiment (Anderson and Ingram 1993).

RESULTS AND DISCUSSION

Ammonification, nitrification and net mineralisation were calculated as follows:

$$\text{NH}_4^+ - \text{N} = \text{NH}_4^+ - \text{N} (t + 1) - \text{NH}_4^+ - \text{N} (t)$$

$$\text{NO}_3^- - \text{N} = \text{NO}_3^- - \text{N} (t + 1) - \text{NO}_3^- - \text{N} (t)$$

$$\text{Net mineralisation rate} = \text{NH}_4^+ - \text{N} + \text{NO}_3^- - \text{N}$$

Where $\text{NH}_4^+ - \text{N}$ is the difference between $\text{NH}_4^+ - \text{N}$ at time (t +1) (i.e. after 1 month of incubation) and time t, (i.e. fresh samples), in the uncovered cores.

$\text{NO}_3^- - \text{N}$ is the difference between $\text{NO}_3^- - \text{N}$ at time (t +1) (i.e. after 1 month of incubation) and time t, (i.e. fresh samples), in the uncovered cores.

Changes in mineral nitrogen have been used by several workers as a measure of net mineralisation rate (Popovic 1980; Ellis 1974; Runge 1974 as quoted by Tietema et al 1990).

The results on a monthly basis are shown in **Figure 1** and **Tables 1-3**. **Table 1** gives the ammonification rates in the undisturbed and the pine forest ecosystems. The ammonification rate showed a seasonal as well as a monthly pattern in both ecosystems. Ammonification was significantly higher in the undisturbed than in the pine ecosystem throughout the year, except July. In fact, on an annual basis, ammonification was 27% higher in the undisturbed system than in the pine forest. Highest rates occurred in January, and lowest rates in July in the undisturbed system, while in the pine

forest lowest rates were observed in the month of June. It is interesting to note that these high and low rates occurred at the highest and lowest temperatures respectively, recorded during the year.

Table 1 Ammonification rate (mg N kg soil⁻¹ month⁻¹) in undisturbed and pine forest ecosystems

Month	Undisturbed ecosystem		Pine ecosystem		t-test
	Mean	SD ±	Mean	SD ±	
March	148	19	118	23	*
April	150	17	125	12	*
May	133	19	112	12	*
June	127	9	95	10	*
July	103	12	95	13	ns
August	129	10	111	10	*
September	142	11	125	8	*
October	150	10	128	9	*
November	169	15	129	9	*
December	185	11	131	13	*
January	197	13	134	14	*
February	191	14	131	11	*

* Significant at p=0.05

n s Not significant

This phenomenon can be explained by the fact that the microorganisms involved in ammonification, such as the *Nitrobacter* heterotrophs, are more active during warm weather than during cold periods (Alexander1978). Highest nitrification rates occurred in January in both ecosystems (**Table 2**), and coincided with periods of high temperatures, while lowest nitrification rates were observed in July (undisturbed system) and June (pine forest).

Table 2 Nitrification rate (mg N kg soil⁻¹ month⁻¹) in undisturbed and pine forest ecosystems

Month	Undisturbed ecosystem		Pine ecosystem		t-test
	Mean	SD ±	Mean	SD ±	
March	346	37	305	29	*
April	341	43	299	16	*
May	366	44	274	16	*
June	285	39	250	21	*
July	263	36	260	13	ns
August	302	22	273	12	*
September	313	38	289	13	*
October	296	30	298	24	*
November	409	22	269	31	*
December	428	54	398	30	*
January	475	31	399	22	*
February	447	34	378	26	*

* Significant at p=0.05

n s Not significant

Nitrifying organisms prefer temperatures ranging from 20 to 35°C (Richards et al., 1985), and their metabolic activity decreases with decreasing temperatures. During the whole year, nitrification rate was significantly higher in the undisturbed ecosystem as compared to that in the pine forest.

Table 3 shows the net mineralisation rate for each month of the year in the two systems. Net mineralisation showed the same trend as ammonification and nitrification. Lowest net mineralisation rates were observed in July (undisturbed ecosystem) and June (pine forest).

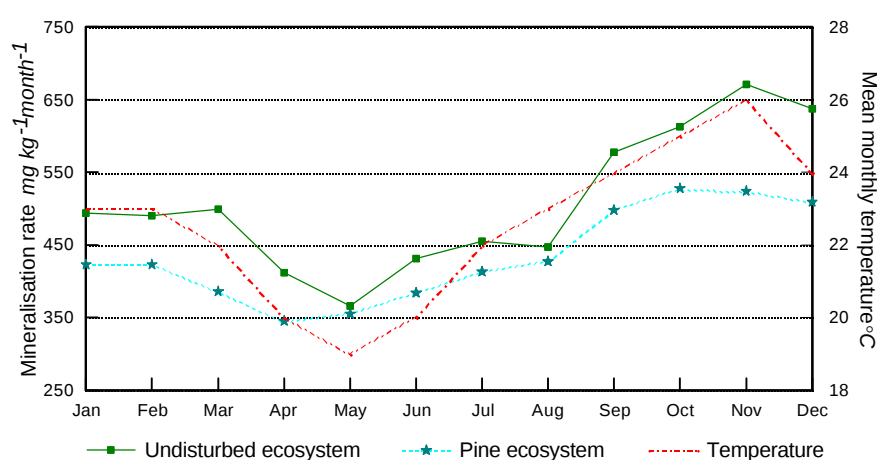
Table 3 Net mineralisation rate (mg N kg soil⁻¹ month⁻¹) and monthly temperatures in undisturbed and pine forest ecosystems

Month	Temp °C	Undisturbed ecosystem	Pine ecosystem
March	23	493*	422.*
April	23	490	423
May	22	499	386
June	20	412	345
July	19	366	355
August	20	431	384
September	22	455	413
October	23	447	427
November	24	578	498
December	25	613	528
January	26	671	524
February	24	638	509

* Significant at p=0.05

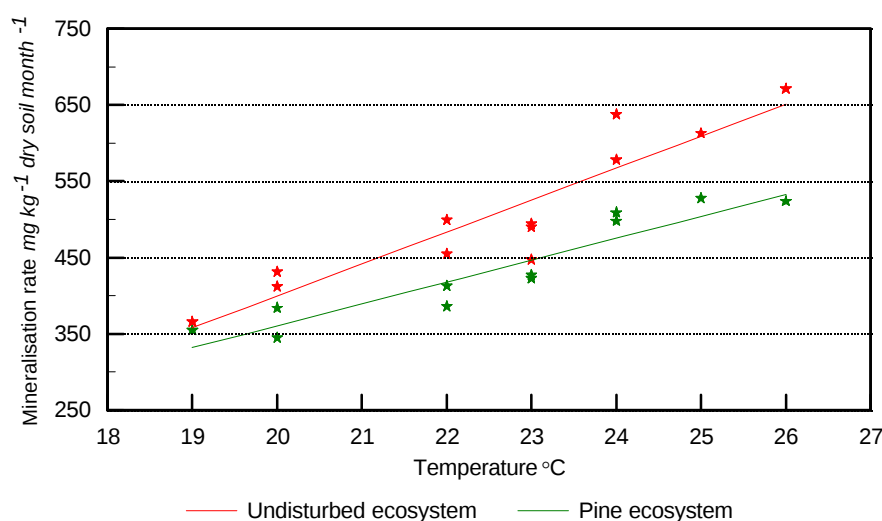
n s Not significant

On an annual basis, the difference in the net mineralisation rate was 1.65 times higher in the undisturbed than in the pine forest. The net mineralisation rate observed in our forest is much higher than has been reported for temperate regions, for example, Tietema et al. (1990) observed that mineralisation rate in an oak beech forest ecosystem was only 87 mg nitrogen /kg dry soil/month from April to October.

Figure 1 Net monthly mineralisation rate and temperature

Ammonification, nitrification and net mineralisation occurred on a seasonal as well as monthly basis and was influenced by temperature (and other factors)(Figure 1). The correlation coefficients between net mineralisation rates and temperature in the undisturbed and pine forest ecosystems were significant ($r = 0.95$ and 0.98 , respectively) (Figure 2).

These reactions are microbiologically mediated and the various organisms involved, such as the general heterotrophs mineralising organic matter and the more specific *Nitrobacter* species (e.g. *Nitrosolus multiformis*) converting ammonium to nitrite, as well as the nitrifiers (e.g. *Nitrosomonas* spp., *Nitrospira gracilis*), are sensitive to environmental and soil factors such as temperature, rainfall, aeration, etc (Alleman and Preston 1998)

Figure 2 Net mineralisation rate versus monthly temperature

The earthworm populations in the two systems were significantly different, being higher in the undisturbed system as compared to the pine forest (**Table 4**).

Table 4 Earthworm populations in undisturbed and pine forest ecosystems

Replicate	Undisturbed ecosystem	Pine ecosystem
R 1	48	29
R 2	37	20
R 3	33	18
Mean	39	22
SD ±	8	6

* significantly different with t-test at 0.05

The influence of terpenes resulting from the breakdown and decomposition of pine needles, and the low pH may be among the responsible factors for this phenomenon. The spatial and temporal variation of denitrification (a subsystem of N-cycling) in any given ecosystem may be very high (Christensen and Tiedje 1988). The drillosphere around the earthworm burrows have been shown to support high numbers of denitrifying microorganisms (Loquet et al. 1977), suggesting that denitrification losses through this process may not be the same in both systems. On the other hand, the enhanced drainage and aeration associated with earthworm activity may have an overall inhibiting influence on denitrification. The mean values of pH, organic matter, and total nitrogen at the beginning of the experiment in both sites are shown in Table 5. The above data show that the soil health is better in the undisturbed ecosystem than in the pine forest, and may have implications in an agroforestry system

Table 5 Properties of soil in undisturbed and pine forest ecosystems

Soil property	Undisturbed ecosystem		Pine ecosystem	
	Mean	SD $\pm$	Mean	SD $\pm$
pH	5.2	0.3	4.3	0.4
Organic matter %	12.4	2.1	9.7	1
Total nitrogen %	0.86	0.08	0.69	0.14

This experiment used a closed system in which some of the fluxes and transformation concerning nitrates are blocked. The PVC tubes prevented input of nitrogen from throughfall and stem flow as well as the uptake of nitrogen by vegetation. On the other hand, leaching of mineral nitrogen to the underlining soil layers and possible losses of nitrogen through denitrification were not prevented. However, denitrification losses in forest soils have been shown by Hutchinson and Mosier (1981). This method therefore slightly underestimates denitrification. Lang (1986), as quoted by Tietema et al. (1990) reported that nitrate nitrogen loss by denitrification was within the range of accuracy of nitrification data obtained by measuring N₂O during incubation.

As can be seen from Tables 1 and 2, mineralisation shows spatial variability. This method, although not very suitable for absolute mineralisation rate, is nonetheless quite satisfactory for comparison purposes (Popovic 1980). The isolation of the soil due to the PVC pipes may have changed the mineralisation-immobilisation subsystem. Dead roots may have caused increased immobilisation followed by increased mineralisation (Popovic, 1980), depending upon the incubation period, for example, the secretion of carbohydrates by living roots that stimulate mineralisation may have been stopped by this method. The duration of the incubation period was chosen taking into consideration the fact that changes in ammoniacal nitrogen and nitrate nitrogen at the end of the experiment should be measurable by the method used. The method of using perforated tubes was preferred over other methods such as sieved and/or mixed soil samples used by other workers (Ohta and Kumada, 1978; Runge, 1974 as quoted by Tietema et al., 1990; Schimel and Parton, 1986). According to Nordmeyer and Richter (1985), disturbance of soil samples may cause increased mineralisation rate. Other workers have used homogenised soil samples (Gordon and van Cleve 1983; Lang 1986) or intact soil cores (Nadelhoffer et al. 1984). This study shows that net mineralisation rate was significantly higher in the undisturbed ecosystem as compared to the pine ecosystem, with higher earthworm populations in the former. It also implies a higher rate of nutrient cycling in such a system, and has implications for fertiliser recommendations in an agroforestry system.

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THE CITRUS PEST, *PHYLLOCNISTIS CITRELLA* STANTON AND ITS CONTROL IN MAURITIUS

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ABSTRACT

The citrus leafminer (*Phyllocnistis citrella* Stainton Lepidoptera: Gracillariidae) first recorded at Labourdonnais in 1995 has become an important pest in commercial orchards, backyard gardens and nurseries throughout the island. Synthetic pyrethroids, carbamates and organophosphates were used to control *P. citrella* at flushing period of citrus. In 1996 and 1997, Imidachloprid (Confidor 200 SL) and the new product, Acetamiprid (Mospilan 20 SP) were tested against CLM. Confidor 200 SL was tested on Pamplemousses trees at Pointe aux Piments and both Confidor and Mospilan were tested on Dancy cultivar in a commercial orchard at Labourdonnais. Treatments were done in a randomised block design. Citrus trees whose trunks were treated with Imidachloprid concentrate at flushing period were free from CLM attack for a period of three months. Foliar applications of Acetamiprid were effective against *P. citrella* for two weeks.

Keywords: *Phyllocnistis citrella*, citrus leafminer, Lepidoptera, insect control, insecticides, Imidachloprid, Acetamiprid, Mauritius.

INTRODUCTION

The citrus leafminer (CLM), *Phyllocnistis citrella* (Lepidoptera: Gracillariidae, Phyllocnistinae) is a major pest of citrus causing extensive damage to new leaf flush. CLM is native of subtropical and tropical Asia (CAB 1986) and is a serious pest of citrus in China (Zhang et al. 1994) and increasingly in many other regions of the world (Beattie et al 1995). The pest was first recorded in Mauritius in 1995 in a commercial orchard at Labourdonnais and has been detected in other citrus growing areas throughout the island. It has become an important pest in commercial orchards, backyard gardens and nurseries throughout the island.

During its larval stages, *P. citrella* mines the adaxial and abaxial surfaces of new leaves. Injured leaves curl, become chlorotic then necrotic. Consequently heavily infested leaves (>4 mines per leaf) are frequently distorted and may abscise (Pena and Duncan 1993). Characteristic silvery mines are produced during the feeding stage of the first larval instars. The silvery appearance is due to the air and condensed water vapour trapped in the mine. As the leaves mature, they are not liable to attack. In cases of massive infestation, CLM attacks even young fruits (Heppner 1995). In Mauritius, CLM mines have once been observed on a young local Pamplemousses fruit at Pointe aux Piments. Larvae of *P. citrella* during severe infestations also attack tender twigs. Such injury can be severe causing die back and consequently reducing tree vigour and productivity (Sabine 1971). Infection by citrus canker has been observed on leaves damaged by *P. citrella* in Mauritius. The pathogen in form of pustules is more abundant along the mines on the damaged leaves. There could also be an association of *P. citrella* with citrus canker. (Cook 1988) stated that *P. citrella* can disseminate the citrus canker bacterium but there is no evidence to support this claim. Broad-spectrum insecticides (pyrethroids, carbamates and organophosphates) are generally used against *P. citrella* (Zhang et al 1994). Several insecticides have been used against *P. citrella* in different countries of the world (**Table 1**). In Mauritius, since 1995, protection of citrus trees against CLM involved the regular spraying of each successive flush with Deltamethrin (Decis 2.5 EC), Cypermethrin (Cymbush 10 EC), Methomyl (Lannate 90 SP), Omethoate (Folimat 50 EC) and Azinphos-methyl (Gusathion 35 EC).

Table 1 Insecticides used against *P.citrella* in different countries of the world

Active ingredient	Family	Trade name	Dosage / hl	Effectiveness	Efficacy
Abamectin	Avermectin	Vertimec	30 ml +0.5% oil	100% mortality	89% mortality after 2 weeks. 20% mortality after 22 days
Diflubenzuron	Benzoyl urea	Dimilin	60g + 500 ml oil	96% mortality 7days after treatment	90% mortality after 14days
Hexaflumuron	Diflurorben-zoyl	Consult 10 EC	75 ml or 50 ml + oil	In case of severe infestation	Severe attack efficacy over 7-8 days; In case of normal attack efficacy over 15 days
Imidacloprid	Nitromethylene compound	Confidor 20 SL	50 ml +oil (Agritexa)	84-100% mortality 7 days after treatment	Depending upon the degree of attack, efficacy for 2-3 weeks
Deltamethrin	Synthetic Pyrethroid	Decis	70 ml + 0.5% oil (Citrole or Ovipron)	7 days after treatment	-

Source: Étude bio-écologique des parasitoïdes indigènes de la mineuse des agrumes, *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae) à l'Ile de la Réunion(1997).

The current study was conducted to test and compare the efficacy of Imidacloprid (Confidor 200 SL) and a new product, Acetamiprid (Mospilan 20 SP) against *P. citrella* during 1995 and 1997. Imidacloprid is a systemic insecticide, with a very good root systemic action and with contact and stomach action. Acetamiprid is also a systemic insecticide and has a high systemic and translaminar action.

MATERIALS AND METHODS

Trial 1 Twelve citrus trees (7 year-old) of the local Pamplemousses (200-250 cm in height and trunk of 15-20 cm in diameter) were randomly selected from the orchard (Experimental Station of the Ministry of Agriculture) at Pointe aux Piments in October 1995.

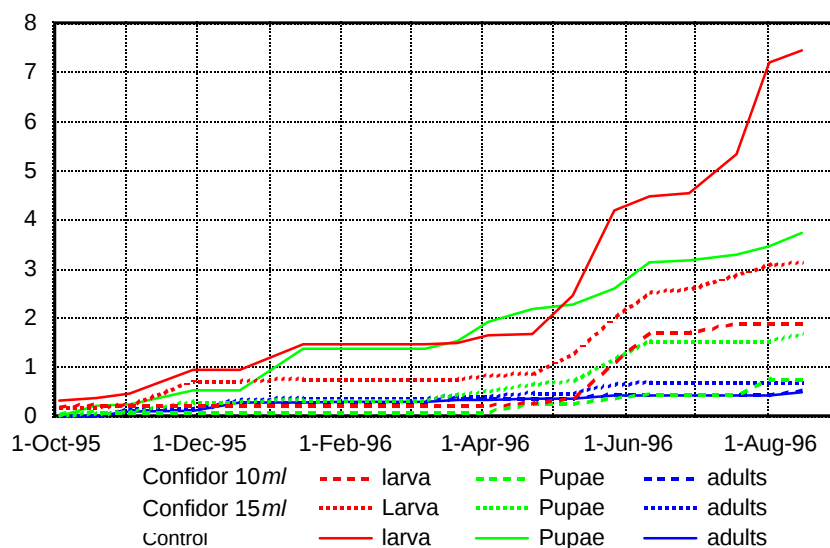
The experiment comprised of three treatments (T1, T2 and T3) allocated in a randomised block design and each treatment consisted of 4 replicates. Trunks of the earmarked trees of T1 and T2 were treated with 15 ml and 10 ml of Confidor concentrate (using a paintbrush) respectively. Trees of T3 were untreated (control). The product was applied only once on 20/10/95 (at flushing period) during the experimental period (October 1995–August 1996). During the same period the number of live larvae and pupae from attacked leaves from T1, T2 and T3 were recorded at 15-day interval. Ruptured pupae (as an indicator for emerged adult moths) were also recorded. The collected data was in terms of live larvae, live pupae, and ruptured pupae for each treatment. Their cumulated average number per leaf was plotted against time (**Table 2 & Figures 1**) and the treatments were compared for significance using ANOVA.

Trials 2 The efficacy of Mospilan 20 SP and Confidor 200 SL were tested in a commercial citrus orchard at Labourdonnais from October 1997 to January 1998. Thirty untreated (one-year old) mandarin trees of Dancy variety (100-150 cm in height and trunk of 3-5 cm in diameter) were selected. The two treatments, T4 with Mospilan and T5 with Confidor were effected in a randomised block design at flushing and trees of T6 were untreated (control). Each treatment was replicated five times with two adjacent trees as one replicate. Three foliar applications of Mospilan (at 2 g per litre of water) were effected to trees of T4 (08/10/97; 22/10/97 and 28/11/97) from October 1997 to January 1998.

Table 2. Cumulative average number of live insect stages per leaf of *P. citrella* in the three treatments at Pointe aux Piments shaddock orchard during 1995-1996.

Date	Larva			Pupae			Ruptured pupae		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
3-Oct-95	0.2	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0
19-Oct-95	0.2	0.2	0.4	0.0	0.1	0.2	0.0	0.0	0.0
2-Nov-95	0.2	0.2	0.5	0.1	0.1	0.2	0.1	0.1	0.3
29-Nov-95	0.7	0.2	0.9	0.3	0.1	0.5	0.1	0.1	0.3
19-Dec-95	0.7	0.2	0.9	0.3	0.1	0.5	0.3	0.3	1.3
15-Jan-96	0.7	0.2	1.5	0.3	0.1	1.4	0.3	0.3	1.5
31-Jan-96	0.7	0.2	1.5	0.3	0.1	1.4	0.3	0.3	2.6
22-Feb-96	0.7	0.2	1.5	0.3	0.1	1.4	0.3	0.3	4.0
7-Mar-96	0.7	0.2	1.5	0.3	0.1	1.4	0.3	0.3	5.7
21-Mar-96	0.7	0.2	1.5	0.4	0.1	1.5	0.4	0.3	5.9
3-Apr-96	0.8	0.2	1.6	0.5	0.1	1.9	0.4	0.3	6.0
22-Apr-96	0.8	0.2	1.7	0.6	0.3	2.2	0.4	0.4	6.5
9-May-96	1.3	0.3	2.5	0.7	0.3	2.3	0.4	0.4	6.6
27-May-96	2.0	1.1	4.2	1.2	0.4	2.6	0.6	0.4	6.7
11-Jun-96	2.5	1.7	4.5	1.5	0.4	3.1	0.7	0.4	7.3
28-Jun-96	2.6	1.7	4.5	1.5	0.4	3.2	0.7	0.4	7.3
18-Jul-96	2.9	1.9	5.3	1.5	0.4	3.3	0.7	0.4	7.3
1-Aug-96	3.0	1.9	7.2	1.5	0.7	3.5	0.7	0.4	7.3
15-Aug-96	3.1	1.9	7.4	1.6	0.7	3.7	0.7	0.5	7.4

Figure 1 Average number of live insects per leaf in treated citrus trees



Two applications of Confidor concentrate (5 ml/trunk) were effected to trees of T5 (08/10/97 and 22/12/97) as per methods used in T1. A low dosage was used because trunks were smaller in size than those in Trial 1. Using the same method as described in trial 1, the number of live larvae from attacked leaves from the treated and the untreated trees were recorded. The treatments were compared for significance using ANOVA.

RESULTS

Trial 1 The average number of live larvae per leaf cumulated in T1 from October 1995 to the first week of May 1996 ranged from 0.16 to 1.27; 0.163 to 0.33 in T2 and 0.31 to 2.4 in T3. From the second week of May to August 1996, the cumulated average number of live larvae ranged from 1.27 to 3.09 for T1, 0.33 to 1.85 for T2 and 2.45 to 7.44 for T3. The increase in larval population was due to the flushing period that started during June and July. There was a significant difference in the average number of live larvae; pupae and emerged adults per leaf between treated trees of T1 and T2 and those of T3 **Table 3.1**.

Table 3.1. Estimated mean live larvae, live pupae and ruptured pupae between treatments at Pointe aux Piments shaddock orchard

Treatments	Live larvae	Live pupae	Ruptured pupae
T1	0.11	0.07	0.04
T2	0.08	0.02	0.02
T3	0.31	0.22	0.48
S.E.±	0.05	0.04	0.05

Trial 2 Larval scouting effected on 30.09.97 gave an average number of 0.13, 0.17 and 0.13 larva per leaf in T4, T5 and T6 respectively. After the first and the second applications of Mospilan, the larval population in T4 was zero until the first week of November **Table 4**. From the 2nd and 4th week of November (14/11- 28/11), there had been an increase in the average number of larvae per leaf that ranged from 0.049 to 0.56 in T4. Following the 3rd treatment, the average number of larvae per leaf dropped from 0.56 to 0.21, passing through a zero larval count on 11th December 1997. The average number of larvae per leaf on trees in T5 was zero from the date of treatment till 28th November 1997 with a negligible count (0.021 larva/leaf) on the 21st. From the 1st to 3rd week of December, there had been a gradual increase in the average number of larvae per leaf from 0.043 to 0.24. After the 2nd treatment (22/12/97) the larval population on leaves again dropped to zero (**Table 4 & Figure 2**).

Figure 2 Average number of larvae per leaf in treated and untreated citrus trees at Labourdonnais orchard

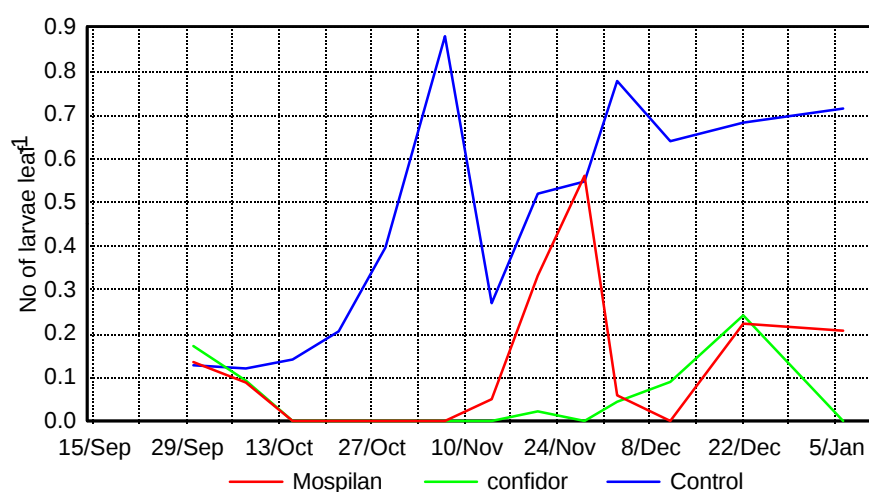


Table 4. Average number of live larvae of *P. citrella* per leaf in the three treatments in Labourdonnais citrus orchard during 1997.

Date	Average No. of larvae / leaf		
	T4	T5	T6
30-Sep-97	0.13	0.17	0.13
8-Oct-97	0.09	0.09	0.12
15-Oct-97	0	0	0.14
22-Oct-97	0	0	0.20
29-Oct-97	0	0	0.40
7-Nov-97	0	0	0.88
14-Nov-97	0.05	0	0.27
21-Nov-97	0.33	0.02	0.52
28-Nov-97	0.56	0	0.55
3-Dec-97	0.06	0.04	0.78
11-Dec-97	0	0.09	0.64
22-Dec-97	0.22	0.24	0.68
6-Jan-98	0.20	0	0.71

There was a significant difference in the average number of larvae per leaf between the treatments (T4 and T5) and the control T6 (**Table 3.2**).

Table 3.2. Estimated mean live larvae between treatments in Labourdonnais orchard

Treatment	T4	T5	T6
Means	0.79	0.74	0.97
S.E±.		0.03	

DISCUSSION

The total mean of live *P. citrella* indicates a pest population of 0.07, 0.04 and 0.33 per leaf in treatments T1, T2 and T3 respectively. Considering the mean number of live *P. citrella* in untreated plot T3 as actual pest population on local Pamplemousses trees, the estimated live pest population in treatment T1 was 22% and 11.9% in T2. This represents a reduction of 78% and 88.1% of the pest population in T1 and T2 respectively (**Table 5**).

Table 5 Estimated % of *P. citrella* population in different treatments at Pointe aux Piments and Labourdonnais orchards.

Treatments	% Live <i>P. citrella</i>
T1 15 ml Confidor	22
T2 10 ml Confidor	12
T3 Control	100
T4 Mospilan	27
T5 Confidor	10
T6 Control	100

Treatments with 10 ml (T2) and 15 ml (T1) of Confidor concentrate on trunks of citrus were both effective against the pest for a period of six months as from the application date. However, the treatment with 10 ml of the Confidor concentrate provided a greater reduction (88 %) in pest. There had also been a progressive reduction in the immature stages (larvae and pupae) of *P. citrella* during the experiment. The two successive treatments with Mospilan (T4) at a fortnightly interval brought a total reduction in the pest population for one month. The 3rd treatment on 28th November checked the larval population to zero level.

Treatment T5 had maintained a zero CLM population for one and a half-month. This result differs from that of Trial 1 because of the difference in dosages, i.e., 5 ml of concentrate in T5; 15ml and 10ml in T1 and T2. Taking the average number of live larvae in T6 as the actual population, the estimated live *P.citrella* in T4 and T5 was 27% and 10% respectively, thus corresponding to 73% pest reduction in T4 and 90% in that of T5 (**Table 5**).

CONCLUSION

Both Mospilan and Confidor have proved effective against *P.citrella*. Foliar treatment with Mospilan ensures CLM control for 15 days. The trunk application with Confidor has given a prolonged control effect for at least three months. The trunk application technique is advantageous because there is a reduction in the frequency of application in citrus orchards and a minimum exposure of the broad-spectrum insecticide to beneficial insects. Further tests are to be carried out to confirm the efficacy of confidor at low doses.

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MONITORING OF SOME INSECTICIDE RESIDUES IN VEGETABLES AND FRUITS AT THE MARKET LEVEL

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ABSTRACT

The amount of some insecticide residues in seasonal vegetables and fruits was monitored at the market level throughout the year 1997. Locally produced vegetables and fruits were purchased from main urban and rural markets and analysed by gas liquid chromatography for pesticide residues. A total of 126 samples of vegetables and 2 samples of fruits were extracted and analysed for insecticide residues. 115 samples of the vegetable and fruit extracts were analysed for the presence of the pyrethroid insecticides cyfluthrin, cypermethrin and deltamethrin. 52 samples of the vegetable and fruit extracts were analysed for the presence of organophosphorus insecticide dichlorvos, diazinon, fenitrothion, methamidophos, profenofos, phosphamidon, malathion and parathion. The data showed that most of the vegetable and fruit samples analysed did not contain residues of the monitored insecticides above the accepted maximum residue limit (MRL) as adopted by the FAO/WHO Codex Alimentarius Commission (CAC), although some insecticide residues have been detected in certain samples only. The following insecticides have been detected in some of the samples of vegetables and fruits analysed, but they have been mostly detected below the MRL: cypermethrin, deltamethrin, methamidophos, profenofos and malathion. The results obtained showed that 61.5% of the vegetable and fruit samples analysed contained no detectable level of the monitored insecticides, 36.2% of the samples gave results with levels of insecticide residues below the MRL, while 2.3% of the samples showed results above the MRL. Only 3 samples contained levels of insecticide residues above the MRL.

Keywords : insecticide-residues, residues, insecticides, maximum residue limits, vegetables, fruits, Mauritius.

INTRODUCTION

Pesticides are chemicals that are utilised by farmers to help them to produce their crops. Pesticides used in agriculture include insecticides, fungicides and herbicides. In vegetable and fruit production, insecticides are used to control pests and fungicides to control diseases. They are directly applied to the crops and some may still be present as residues in the vegetables and fruits after their harvests. It is true that insecticides and fungicides are toxic substances, but when used properly they constitute an important input in vegetable and fruit production in order to produce economically marketable products.

On the one hand people are encouraged to consume more vegetables and fruits, these being a good source of vitamins and fibre and also beneficial to their health - and on the other hand, the mass media have rightly created an awareness about, but wrongly magnified the environmental and health problems and the risk involved in the use of chemicals, especially pesticides, in agriculture. Consequently, this has created a certain apprehension and fear in the public as to the presence of pesticide residues in their daily food. The public is confused and alarmed about food safety. The results of a market survey carried out during the year 1997 to determine the level of residues of some insecticides in the seasonal vegetables and fruits available on the local markets are presented to give a truer picture of the situation.

MATERIALS AND METHODS

Locally produced vegetables and fruits were purchased from the main urban and rural markets of the country throughout the year 1997 and analysed by gas liquid chromatography for pesticide residues. The seasonal vegetables and fruits analysed included tomatoes, cabbage, cauliflower, lettuce, watercress, and beans, golden squash (patisson), mustard greens (brèdes De Chine), Chinese cabbage (petsai), pineapple and mandarin. The markets where these vegetables and fruits were purchased included those of Port Louis, Vacoas, Curepipe, Rose Hill, Quatre Bornes, Chemin Grenier and Mahebourg. A total of 126 samples of vegetables and 2 samples of fruits (the peel and pulp separately) were extracted and analysed for insecticide residues by procedures adapted from methods available in the literature. (McLeod and Ritcey 1973; Thier and Zeumer 1987).

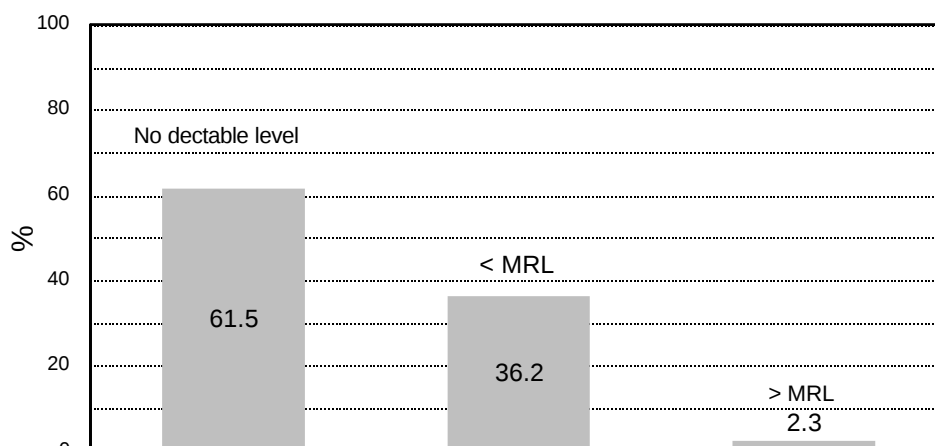
115 samples of the vegetables and fruits were extracted for pyrethroid insecticide residues and these extracts were analysed for the presence of the pyrethroid insecticides: cyfluthrin (Baythroid), cypermethrin (Cybush) and deltamethrin (Decis), using the gas liquid chromatograph equipped with Electron Capture Detector. 50 samples of the vegetables and one sample of pineapple were also extracted for organophosphorus insecticide residues. These extracts were analysed for the presence of organophosphorus insecticides using the gas liquid chromatograph equipped with Nitrogen Phosphorus Detector. The organophosphorus insecticides screened included dichlorvos (DDVP), diazinon, fenitrothion (Folition), methamidophos (Tamaron), profenofos (Selecron), phosphamidon (Dimecron), malathion and parathion.

RESULTS AND DISCUSSION

The data showed that most of the vegetable and fruit samples analysed did not contain residues of the monitored insecticides above the accepted maximum residue limit (MRL) as adopted by the FAO/WHO Codex Alimentarius Commission (CAC) (1993), although some insecticide residues have been detected in certain samples only. The results obtained showed that 61.5% of the vegetable and fruit samples analysed contained no detectable level of the monitored insecticides, 36.2% of the samples gave results with trace levels of insecticide residues or levels below the MRL, while 2.3% of the samples showed results above the MRL (**Figure 1**).

Only 3 samples contained levels of insecticide residues above the MRL. The following insecticides have been detected in some of the samples of vegetables and fruits analysed, but they have been mostly detected below the MRLs: cypermethrin, deltamethrin, methamidophos, profenofos and malathion.

Details of the amounts of pyrethroid and organophosphorus insecticide residues detected in the various vegetables and fruits analysed are summarised in **Tables 1 and 2**.

Figure 1 Insecticide residues found in vegetables and fruits samples in 1997**Table1** Pyrethroid insecticide residues in vegetables and fruits for the year 1997

Vegetables and fruits	Total No of samples	Cypermethrin			Deltamethrin		
		Range $mg\ kg^{-1}$	No of samples	MRL	Range $mg\ kg^{-1}$	No of samples	MRL
Tomatoes	15	0.01-0.41	11	0.5	0.004-1.07	8	0.2
Cabbage	15	0.013	1	1.0	0.017	1	0.2
Cauliflower head	8	0.04-0.06	2	1.0	NDL		0.2
Cauliflower leaves	8	0.47-1.12	2	1.0	0.02	1	0.2
Lettuce	15	0.74	1	2.0	0.002	1	0.5
Watercress	16	0.02-0.97		2.0	0.003-0.097	3	0.5
Beans	16	0.013-0.27	5	0.5	0.011	1	0.1
Golden Squash (Patisson)	14	0.014	1	0.2	0.008	2	0.2
Mustard greens (Brede de Chine)	2	0.42	1	1.0	0.084	1	0.2
Chinese Cabbage (Petsai)	2	NDL			NDL	-	
Pineapple (peel)	1	NDL			-		NDL
Pineapple (pulp)	1	NDL			-		NDL
Mandarin (peel)	1	NDL			0.215		0.05
Mandarin (pulp)	1	NDL			-		NDL
Total	115		24			18	

MRL – Maximum Residue Limit

NDL – No Detectable Level

It can be seen that the pyrethroid insecticide residues have been mostly detected in tomatoes, watercress and beans. Cypermethrin has been found in 73% of the samples of tomatoes analysed, 37% of the samples of watercress and 31% of the samples of beans, whereas deltamethrin has been found in 53% of the samples of tomatoes and 19% of the samples of watercress analysed (**Tables 1& 3, Figure 2**). The organophosphorus insecticide residues have been detected in trace amounts in a few samples (2-3) of tomatoes, cabbage, watercress, beans and golden squash (patisson), and also in the cauliflower and pineapple samples analysed. (**Tables 2 & 4, Figure 3**)

Figure 2 Frequency of detection of *cypermethrin* and *deltamethrin* in vegetables in 1997

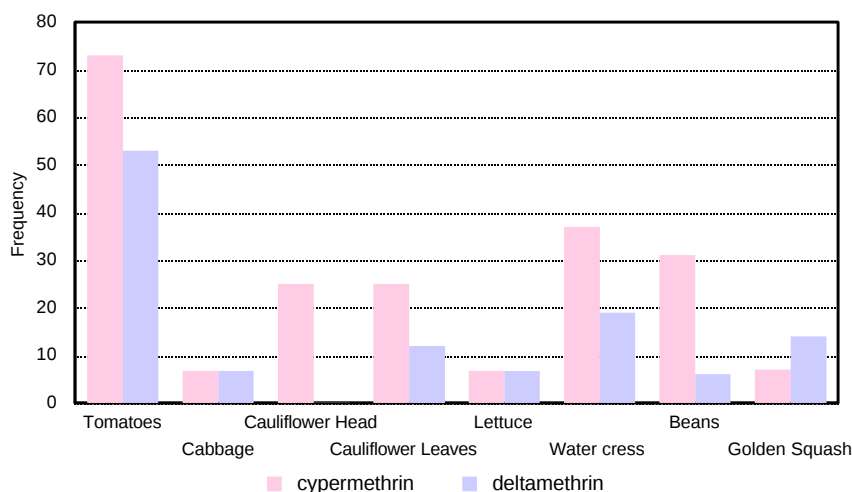


Table 2 Organophosphorus insecticide residues in vegetables and fruits for the year 1997

Vegetables and fruits	Total No of samples	Methamidophos			Profenofos			Malathion		
		Range mg kg ⁻¹	No of samples	MRL	Range mg kg ⁻¹	No of samples	MRL	Range mg kg ⁻¹	No of samples	MRL
Tomatoes	8	NDL			0.011-0.076	3	2			
Cabbage	8	0.008-0.14	3	1			-			
Cauliflower head	1	0.13		1	NDL		-	NDL		
Cauliflower leaves	1	0.14		1	NDL		-			
Lettuce	8	NDL	-		NDL		-	NDL		
Watercress	8	NDL	-		0.15-0.28	2	1			
Beans	8	0.004-0.032	2	0	0.003	1		NDL		
Golden Squash (Patisson)	8	0.004-0.012	3							
Pineapple peel	1	NDL	-		-	0.3				NA
Pineapple pulp	1	NDL	-		-	NDL				
Total	52									

MRL – Maximum Residue Limit

NDL – No Detectable Level

NA - As an indication, the MRL for other fruits like Apple is 2, Citrus Fruits is 4, Peach is 6 and Pear is 0.5, all units being in mg per kg

Table 3 Frequency of detection of *Cypermethrin* and *Deltamethrin* in vegetables and fruits for the year 1997

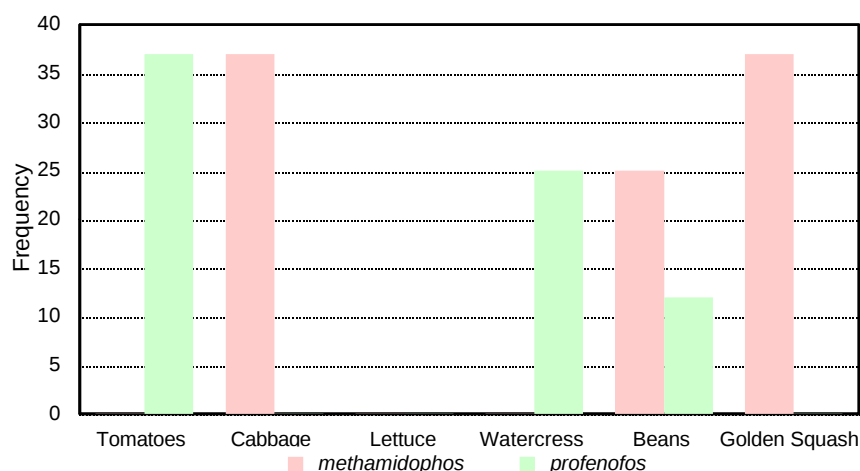
Vegetables and fruits	Samples						
	Analysed	<i>Cypermethrin</i>			<i>Deltamethrin</i>		
		Nos	%	>MRL	Nos	%	>MRL
Tomatoes	15	11	73	0	8	53	1
Cabbage	15	1	7	0	1	6.7	0
Cauliflower Head	8	2	25	0	0	0	0
Cauliflower Leaves	8	2	25	1	1	12	0
Lettuce	15	1	7	0	1	6.7	0
Watercress	16	6	37	0	3	19	0
Beans	16	5	31	0	1	6	0
Golden Squash (Patisson)	14	1	7	0	2	14	0
Brèdes de Chine	2	1	50	0	1	50	0
Petsai	2	0	0	0	0	0	0
Pineapple peel	1	0	0	0	0	0	0
Pineapple pulp	1	0	0	0	0	0	0
Mandarin peel	1	0	0	0	1	100	1
Mandarin pulp	1	0	0	0	0	0	0
Total	115	30	26	1	19	16	2

MRL – Maximum Residue Limit

Table 4 Frequency of detection of *Methamidophos* and *Profenofos* in vegetables and fruits for 1997

Vegetables and fruits	Samples						
	Analysed	<i>Methamidophos</i>			<i>Profenofos</i>		
		Nos	%	>MRL	Nos	%	>MRL
Tomatoes	8	0	0	0	3	37	0
Cabbage	8	3	37	0	0	0	0
Cauliflower Head	1	1	100	0	0	0	0
Cauliflower Leaves	1	1	100	0	0	0	0
Lettuce	8	0	0	0	0	0	0
Watercress	8	0	0	0	2	25	0
Beans	8	2	25	0	1	12	0
Golden Squash (Patisson)	8	3	37	0	0	0	0
Pineapple peel	1	0	0	0	0	0	0
Pineapple pulp	1	0	0	0	0	0	0
Total	52	10	19	0	6	11	0

MRL – Maximum Residue Limit

Figure 3 Frequency of detection of *methamidophos* and *profenofos* in vegetables for the year 1997

Details of the three cases where the MRLs have been exceeded are shown in(**Table 5**). It is interesting to note that in the sample of cauliflower leaves where cypermethrin has been found to be above the MRL value (1.0 mg per kg), the amount of cypermethrin detected in the corresponding cauliflower head was only 0.06 mg per kg. Similarly in the mandarin sample under test, the edible pulp contained no detectable level of deltamethrin, whereas the peel has been found to contain deltamethrin above the MRL.

Table 5 Pesticide residues in vegetables and fruits

Market	Sample	Pesticide	Residue <i>mg kg⁻¹</i>	MRL <i>mg kg⁻¹</i>
Curepipe	Tomatoes	<i>deltamethrin</i>	1.07	0.2
Vacoas	Cauliflower leaves	<i>cypermethrin</i>	1.12	1
Vacoas	Corresponding Cauliflower head	<i>cypermethrin</i>	0.06	1
Curepipe	Mandarin peel	<i>deltamethrin</i>	0.21	0.05
Curepipe	Corresponding mandarin pulp	<i>deltamethrin</i>	NDL	0.05

MRL – Maximum Residue Limit NDL – No Detectable Level

The maximum residue limits (MRLs) have been established for individual pesticide/crop combinations by the Joint FAO/WHO Meetings on Pesticide Residues (JMPR), using residue data from supervised trials and uses of pesticides including good agricultural practices (GAPs) (Anon. 1993). Hence they can serve as an indication for determining whether GAPs are carried out by the producers. The MRL is not a toxicity level and has nothing to do with toxicology (Roberts 1991). It is rather the level above which residues should not occur if the pesticide has been used as recommended and according to GAPs (Roberts 1991).

From our study only 3 cases have been observed to exceed the MRL. These may be due to non observance of certain recommended agricultural practices like respecting the safety interval between the last pesticide application and the harvest of the crop or using the recommended rate of pesticide application. In order to avoid such occurrences, the producers should adhere to the recommended, authorised and correct ways of using pesticides to control pests and diseases in their crops. These chemicals are toxic by nature, but when used in the appropriate and safe manner as specified on the labels, they should not be harmful to the user, the consumer or the environment. It is their mis-use, which can be a source of hazards.

It should be noted that in this market survey, the vegetables and fruits were analysed as such from the markets, and if cleaned and washed they should contain less insecticide residues. Washing of

agricultural produce is known to reduce the levels of residues, which can be dissolved or physically dislodged from the raw product (Chin 1991). The consumer should also be aware of the concept of the Acceptable Daily Intake (ADI) in the evaluation of the safety of pesticide residues in foods. The ADI of a pesticide is the amount of that pesticide that can be ingested daily by man during an entire lifetime without an appreciable risk to the health of the consumer on the basis of all the known facts (Anon. 1993). It is expressed in milligrams per kilogram of body weight and is obtained from toxicological studies. The ADIs of some pesticides have been established by the Joint FAO/WHO Meetings on Pesticide Residues and are published in (Codex Alimentarius – Pesticide Residues in Food Volume 2 1993 and 1996) (Table 6). So when trace levels of pesticide residues are detected in our food, this does not mean that it is unsafe for consumption.

Table 6 Acceptable daily intakes (ADIs) of some insecticides

Compound	Trade Name	ADI mg kg^{-1} body weight
<i>Cypermethrin</i>	Cymbush	0.050
<i>Deltamethrin</i>	Decis	0.010
<i>Methamidophos</i>	Tamaron	0.004
<i>Profenofos</i>	Selecron	0.010
<i>malathion</i>	Malathion	0.020

SOURCE: Codex Alimentarius. Pesticide residues in food – Maximum residue limits. Volume 2B. Second Edition. 1996. FAO/WHO

The concern raised in the public by harmless but detectable trace levels of pesticide residues in foods is probably overemphasised. It has been pointed out that the hazard to humans from low doses of substances shown to be rodent-carcinogens has been overestimated (Richardson 1991). It should also be noted that pesticides could occur naturally. Plants synthesise a high variety of toxins for their protection against fungi, insects and animal predators and these natural pesticides occur in very much larger chemical structure types and at levels sometimes higher than synthetic pesticides (Richardson 1991). Some of these natural pesticides have been shown to have carcinogenic properties, and despite this fact epidemiological evidence suggests that the intake of vegetables by humans and other animals can and does reduce cancer, e.g. by ingestion of vitamin C (Richardson 1991).

CONCLUSION

From the results obtained, it can be concluded that most of the vegetable and fruit samples analysed did not contain residues of the monitored insecticides above the maximum residue limit (MRL), although some insecticide residues have been detected in certain samples only. The public therefore should not be concerned about any excessive amounts of pesticide residues being present in the local vegetables and fruits available on the market. There were occasional cases where the MRLs have been exceeded. But this can be avoided by inculcating in the growers, the necessity to strictly follow the recommended and correct ways of using pesticides.

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INCIDENCE OF VIRUS DISEASES IN TOMATO

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ABSTRACT

*The incidence of virus diseases of tomato (*Lycopersicon esculentum*) in Mauritius was investigated in fields samples by electron microscopy and enzyme-linked immunosorbent assay (ELISA). Two virus diseases, potato virus Y (PVY) and tomato mosaic virus (ToMV) were found to be widespread. ELISA may differentiate two strains of the PVY virus. Samples collected from 1995 to 1997 showed a marked prevalence of PVY^o with respect to PVY^N in tomato. A host preference seemed to be present with PVY^N mostly confined to potato and PVY^o to tomato, although the latter strain is also common on potato. The high incidence of PVY indicates transmission by aphid vectors. The spread of the two viruses was followed in a field at Médine on varieties Sirius and MST 32/1. Measures such as seed treatment, reducing plant density and frequent handling of plants, and avoiding clipping of plants resulted into practically virus-free plantations. The need for a global strategy in the control of virus diseases of tomato is discussed.*

Keywords: tomatoes, *Lycopersicon esculentum*, plant viruses, potato virus Y, tomato-mosaic-virus, transmission, ELISA, disease control, Mauritius.

INTRODUCTION

Tomato is one of the most versatile vegetables in Mauritius and local production caters for consumption of the fresh produce. The average annual production of cooking tomato is about 13 000 tonnes and the average yield is in the range of 11 t ha⁻¹, while the worldwide yield averages 26 t ha⁻¹. There is therefore much scope for increasing tomato production in Mauritius. Small-scale growers produce 95% of the total local consumption. Bacterial wilt and virus diseases are considered by growers as the two major groups of diseases affecting production, probably owing to the fact that they cannot be chemically controlled (Govinden et al 1997).

Several pathogens affecting tomato (*Lycopersicon esculentum*) have been reported in Mauritius (Orieux and Felix 1968). Of those recorded, the most widespread and economically important are as follows: Pathogens of fungal aetiology: late blight (*Phytophthora infestans*) and early blight (*Alternaria solani*). Pathogens of bacterial aetiology: bacterial wilt (*Ralstonia solanacearum*). Viral pathogens: Tomato mosaic virus (ToMV), and cucumber mosaic virus (CMV). Bacterial spot (*Xanthomonas campestris* pv *vesicatoria*), bacterial speck (*Pseudomonas syringae* pv *tomato*) and potato virus Y (PVY) have since been detected and have gained economic importance. The fungal and bacterial diseases are adequately controlled by fungicides and / or appropriate cultural practices, but viral diseases are difficult to control and can result in substantial crop losses (MSIRI 1998). Their incidence and severity vary from season to season because of the complex inter-relationships that exist among the pathogen, host, vector, virus source and environment (Jones et al 1991). Owing to the unpredictability of disease losses, growers often neglect the adoption of control strategies on a regular basis. A study on the epidemiology and symptomatology of virus diseases on tomato in Mauritius was initiated in 1995 to identify the pathogens and to determine their relative distribution. The results are presented and management strategies to control virus diseases are discussed in this paper.

MATERIALS AND METHODS

Surveys

1995

Weekly surveys initiated in April were carried out in the Médine factory area at Albion, Tamarin (Mon Désir Wolmar), Tamarin (Mon Désir Surface) and Bassin. Variety *MST 32/1* and to a lesser extent variety *Sirius* were planted at the first 3 sites. To investigate symptomatology to virus infection, a systematic survey was also carried out on 15 varieties of salad tomato grown from imported seeds at Bassin. The varieties were *Elios*, *Caston*, *Orb*, *Perfect Peel*, *Aledo*, *Early Melch*, *Peto*, *Marmande*, *Floradade*, *Rio Grande*, *Rimone*, *Coudoulet*, *Mecline*, *Promo* and *Cycalou*. Samples (78 altogether) from at least 5 plants of each variety were randomly collected from plants showing symptoms and plants without symptoms. Samples were tested for PVY, ToMV and CMV infection. Those showing leaf roll symptoms were tested for potato leafroll virus (PLRV). Symptoms were noted and samples tested by enzyme-linked immunosorbent assay (ELISA) or electron microscopy (EM) for virus identification.

Samples from different regions were also occasionally tested. Surveys were carried out at weekly intervals starting one week after plantation. Altogether, 115 samples were examined. Seedlings in the Médine factory area were all transplanted from the nursery at Médine Sugar Estate. Fifty samples of seedlings from 5 different beds in the nursery were tested for ToMV before the application of the seed treatment recommendation. After the application of cultural practices such as seed treatment, low sowing density and minimal handling of seedlings, tests were carried out on 20 samples.

1996

Surveys spanned over the whole year from January to November and continued mainly in the Médine Sugar Estate tomato production area with occasional surveys in other production areas. Altogether 150 samples were tested. Depending upon peculiarity of symptoms, the viruses tested for were PVY (with strain differentiation where applicable), ToMV, CMV, PLRV and tomato spotted wilt virus (TSWV). Symptoms similar to those associated with tomato yellow leaf curl virus (TYLCV) i.e. yellowing, severe leaf curl and stunting were encountered in the fields. Forty-five samples including those with TYLCV-associated symptoms were spotted on Hybond nylon membranes and sent to the Asian Vegetable Research and Development Centre (AVRDC), Taiwan, for detection of TYLCV by nucleic acid spot hybridisation.

1997

With the appearance of TYLCV in the neighbouring Réunion Island, surveys were carried out in different regions, paying special attention to plants showing associated symptoms. One hundred and seven samples were tested altogether from January to October, of which 15 were spotted on Hybond and nitrocellulose membranes to be tested at AVRDC. Mechanical transmission to healthy tomato plants was carried out using sap extracts from two plants with TYLCV symptoms - one from a small planter's field in Triolet showing small yellowing crinkled leaves and veinal necrosis and one from Médine (Roches Brunes) showing stunted growth, bunchiness and yellowing.

Identification of viruses

Disease diagnosis was confirmed by the double antibody sandwich ELISA method (DAS-ELISA) according to the procedures described by Clark and Adams (1977) as well as by electron microscopy.

DAS- ELISA

All reagents were obtained commercially. Leaf samples were extracted at a dilution of 1:5 in the appropriate buffer, microfuged at 10 000 g for 5 min before addition to the specific IgG-coated plates.

Absorbances at 405 nm were determined spectrophotometrically, using a Dynex MRX microplate reader.

Electron microscopy

As an alternative to ELISA, electron microscopy was used for detection of ToMV. The quick dip technique was used. Extracted sap was microfuged at 10 000 g for 5 min to remove leaf debris. Copper grids coated with a carbon stabilised formvar film were placed on 20 µl drops of the supernatant for one minute and stained by washing off the extract with 10 drops of 2 % phosphotungstic acid, pH 6.8.

Leaf-tissue squashes on membranes

Leaf tissue was squashed on the appropriate membrane and mailed to AVRDC, where ELISA squash blot tests on nitrocellulose membranes were carried out for the detection of PVY, ToMV, CMV and TSWV, or DNA hybridisation tests on nylon membranes for the detection of TYLCV.

RESULTS

1995

Survey at Albion

Only part of the seeds was treated with tri-sodium phosphate. Seedlings presented no symptoms of mosaic or PVY infection. Two weeks later, 7 samples with various symptoms were tested by ELISA. Four were infected with ToMV, 1 with PVY^o and 2 simultaneously with both PVY^o and ToMV. The following week, widespread infection with both PVY and ToMV was observed. Stunted plants with crinkling at the apex when infected at a young stage, and older plants, having started to bear fruits with crinkling only at the apex of certain stems, were shown to be infected with PVY, **Plate 1**. Plants showing leaf curling and mosaic symptoms were infected with ToMV, **Plate 2**. Following these symptoms as guidelines, 20 rows of approximately 100 m were surveyed. Eighty plants showed PVY symptoms and 25 showed ToMV symptoms. Roguing of the PVY infected plants was carried out. On the 4th week, a general survey of the whole field showed 60-75% of the field infected with ToMV and about 20% with PVY.

Plate 1. Bunchy apex symptoms on stunted plant infected with PVY



Plate 2. Leaf curling and mosaic symptoms on plant infected with ToMV



Survey at Tamarin (Mon Desir Wolmar)

The field was planted partly with treated seeds and partly with untreated seeds. As observed in the survey at Albion, but to a lesser extent (30-40%), symptoms of both ToMV and PVY developed 2 weeks after transplantation. ELISA tests confirmed infection by both viruses. ToMV was present in plants issued from both treated and untreated seeds. More than 100 plants were rogued due to PVY

infection. PVY was detected in plants showing crinkling symptoms or small rolled leaves without mosaic symptoms. Plants showing leaf roll symptoms were tested for PLRV but no PLRV was detected.

Survey at Tamarin (Mon Desir Surface)

The field planted entirely with treated seeds was generally healthy, **Plate 3**. Visual surveys revealed a low percentage of virus-infected plants, which were rogued and samples brought to the laboratory for identification. The results are shown in **Table 1**.

Similar types of symptoms were observed at Jolibois, Savannah Sugar Estate in a field planted with treated seeds of variety *MST 32/1*. Out of 9 samples tested, 4 were infected with PVY^o and 5 with mixed PVY^o and ToMV. No CMV and no PVY^N were detected.

Plate 3. Field of *MST 32/1* at Tamarin



Survey at Bassin

Of the 78 samples tested, 57 were infected with PVY, 2 with PVY / ToMV co-infection, 1 with CMV and 18 were virus-free. PVY was encountered in all varieties in samples showing varied symptoms such as slight mosaic and yellowing in *Elios*, yellowing and crinkling in *Aledo*, crinkling and rugosity in *Floradade*, bright yellow mosaic in *Rimone* and without any apparent symptom in *Orb*, *Aledo*, *Peto*, *Coudoulet*, *Promo* and *Cycalou*. PVY / ToMV co-infection caused slight mosaic in *Marmande* and no symptom in *Coudoulet*. The presence of CMV in 1 sample of *Coudoulet* provoked crinkling symptoms. Of the 18 virus-free samples, 3 showed yellowing symptoms, 1 crinkling, 1 leaf rolling and 13 showed no symptoms. Of the 25 symptomless samples, 11 were infected with PVY, 1 was co-infected with PVY and ToMV and 13 were free from viruses tested.

Survey on tomato seedlings in the nursery

Thirty-seven seedlings (74%) were found infected with ToMV before application of recommended cultural practices. Tests carried out afterwards showed no ToMV and no PVY infection.

1996

PVY^o and ToMV were still the most widespread viruses in tomato. Occasionally PLRV and CMV infections were encountered. Symptoms were still found to be varied despite similar virus infection, varieties, location and environment. PVY caused varying degrees of mosaic, yellowing, crinkling, stunting, bunchy top and curling symptoms, PVY / CMV co-infection produced filiform leaves or bright mosaic, PVY / ToMV co-infection was detected in samples with leaf curling, filiform leaves, mosaic, necrotic spots, stunted growth as well as one without apparent symptoms. No TYLCV was detected in samples sent to AVRDC despite the presence of TYLCV-associated symptoms, such as leaf curling and small yellowing leaves.

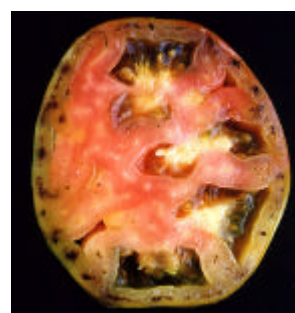
Table 1 Symptomatology and epidemiology of virus diseases at Mon Desir Surface, Médine Sugar Estate

Sample	Variety	Symptoms	Virus detected
1	MST 32/1	Bright yellow mosaic	PVY ^o , CMV
2	MST 32/1	Bright yellow mosaic	PVY ^o
3	MST 32/1	Bright yellow mosaic	-
4	MST 32/1	Bright yellow mosaic, crinkling	PVY ^o , ToMV, CMV
5	MST 32/1	Mosaic	PVY ^o , ToMV, CMV
6	MST 32/1	Mosaic	PVY ^o , ToMV, CMV
7	MST 32/1	Mosaic	CMV
8	MST 32/1	Mosaic	-
9	MST 32/1	Mosaic	PVY ^o , CMV
10	MST 32/1	Mosaic	PVY ^o
11	MST 32/1	Mosaic	PVY ^o
12	MST 32/1	Mosaic, crinkling	PVY ^o , ToMV
13	MST 32/1	Mosaic, necrotic spots	PVY ^o , CMV
14	MST 32/1	Mosaic, necrotic spots	PVY ^o , ToMV
15	Sirius	Mosaic	-
16	Sirius	Mosaic	PVY ^o
17	Sirius	Mosaic	PVY ^o
18	Sirius	Yellowing	PVY ^o
19	Sirius	Yellowing	CMV
20	Sirius	Yellowing, necrotic rim	ToMV
21	Sirius	Veinal necrosis, necrotic spots on leaf, necrotic streaks on stem	PVY ^o , ToMV, CMV

1997

PVY^o and ToMV were once more the most widespread viruses, with CMV detected in only eight samples. Fruits with typical brownwall symptoms caused by ToMV were observed for the first time in salad tomato plants from Britannia, **Plate 4**. Electron microscopic examination of the leaf and of the fruit extracts disclosed presence of ToMV and of a potyvirus. ELISA on the same leaf extract was negative for PVY. This may be attributed either to a very low concentration of PVY or to an unrelated potyvirus. Characteristic symptoms of internal browning on the fruit of variety *Caraibo* were present in fruits infected with ToMV, as confirmed by electron microscopy, Plate 5.

Plate 4. Brownwall symptoms in tomato infected with ToMV and potyvirus **Plate 5.** Internal browning symptoms in tomato infected with ToMV



Neither TYLCV nor any of the other viruses tested were detected in the four samples with TYLCV-associated symptoms. Symptoms of small yellowing leaves developed in healthy tomato upon which mechanical inoculation with extracts from two of the samples was performed.

It is worth noting that out of the 107 samples tested, 56 were derived from plants grown from treated seeds and 51 from untreated seeds. 34% samples from treated seeds were infected with ToMV compared to 57% for samples from untreated seeds.

DISCUSSION

From observations made in the 1995-1997 surveys, it may be concluded that symptomatology is not reliable for virus disease diagnosis. These findings are similar to those of Marchoux et al. No specific symptoms may be attributed to infection with a particular virus. Detection by ELISA or other techniques is necessary to distinguish between ToMV and other insect-transmitted viruses so as to apply the appropriate control measures. Variation of symptoms may be due to viral strain, cultivars, time of infection (both calendar year and stage of plant growth), light intensity, temperature, mixed infections (Jones et al 1991) and/or presence of yet unidentified pathogens.

The major viruses infecting tomato were ToMV and PVY followed by CMV and PLRV. Viruses prevailing in several countries, including the neighbouring Reunion Island, are TYLCV (Peterschmitt et al. 1998) and TSWV. The latter two viruses were not detected in Mauritius despite numerous tests carried out during 1996 and 1997.

ToMV, a tobamovirus, is readily transmitted by contact and by seed and may survive on leaf and root debris in the soil for up to two years under favourable conditions. It generally causes mosaic and leaf curling on leaves, uneven ripening and internal browning or brownwall on fruits of certain varieties (Blancard 1988), but symptoms vary greatly. Seed treatment with a 10% solution of tri-sodium phosphate for 15 minutes eliminates the virus without affecting seed germination. (Jones et al 1991). This treatment seems to be a prerequisite to generate a healthy crop with a low ToMV infection rate. The field at Mon Desir Surface is a good example showing how a combination of measures including cultural practices and disease control may result in a healthy crop and good yield. Although not taking other factors affecting yield into consideration, it is interesting to compare the yield figures provided by Médine Sugar Estate at the 4 sites surveyed **Table 2**.

Table 2 : Tomato yields at Médine SE

Site	Area cultivated <i>ha</i>	Variety	Virus incidence	Yield <i>t ha⁻¹</i>
Albion	2.50	MST 32/1	60-75%	7.2
Wolmar	3.69	MST 32/1	30-40%	22.5
Surface	2.53	MST 32/1	< 10%	28.4
Surface	1.13	Sirius	< 10%	27.4
Bassin	1.00	Salad tomato	30-40%	6.7

PVY, a potyvirus, is efficiently transmitted by many aphid species in a non-persistent manner. PVY^o infected plants exhibit mosaic, leaf crinkling symptoms, not readily distinguishable from ToMV symptoms, and veinal necrosis. In the 'salad tomato' survey, the incidence of PVY infection was quite high, giving inconsistent symptoms even within one variety. Latent infection was detected at a rate of 48%. High aphid populations were noted in an adjacent field of pumpkin (*Cucurbita maxima*), which could explain the high rate of PVY transmission. The necrotic strain of PVY (PVY^N) has been detected only once in tomato although it is quite widespread in potato. PVY^N has been experimentally transmitted by mechanical inoculation to three tomato varieties (*Local*, *MST 32/1* and *Sirius*) (MSIRI 1996). Further studies into the transmission of the virus under field conditions and the apparent host preference of the necrotic strain are required to elucidate the rapid spread of PVY and the near absence of PVY^N in tomato. Weeds such as *Solanum nigrum* can serve as PVY reservoirs (Brunt et al 1990; Jones et al. 1991), and the virus has been detected locally in a sample of the weed with mosaic symptoms. Overlapping plantings of tomato, potato and cucurbits may contribute to the development of high aphid populations and hence to virus spread.

CMV is the type member of the cucumovirus group also transmitted by aphids. Its host range includes many important vegetable crops such as cucurbits, and also ornamentals and plants like banana. Although it has not been found to be widely distributed in tomato, the virus is potentially important because of readily available source of infection and presence of high aphid populations known to create epidemics (Marchoux et al) . PLRV is a luteovirus and is transmitted by aphids in a persistent manner. It is mostly encountered in potato, where it is tuber-borne. The survey has shown that infection in tomato is not significant, but this is the first report of the disease in tomato in Mauritius.

TYLCV, not yet recorded in Mauritius, is a geminivirus, transmitted by adult silverleaf whiteflies, *Bemisia argentifolii* (previously known as *B. tabaci* biotype B, (Polston et al 1994). To date, *B. argentifolii* has not been recorded in Mauritius (Mamet and Williams 1993). The virus may be transmitted through the egg of the vector for at least two generations (Ghanim et al 1998). Symptoms associated with the virus are stunted yellowing plants with leaflets cupped and reduced in size. TYLCV is generally not mechanically or seed transmitted. Another geminivirus infecting tomato and potato is potato yellow mosaic virus (PYMV), which may be transmitted mechanically. TSWV, not yet recorded in Mauritius, is a tospovirus, transmitted by *Thrips tabaci*, and *Frankliniella* species in a persistent manner. Young leaves of infected plants usually turn bronze and later develop numerous small dark spots. The virus has a wide host range and is potentially very damaging. A constant monitoring of tomato fields and vigilance are essential to prevent the introduction of new economically important diseases into Mauritius.

The control of viral diseases in tomato may be achieved by keeping the initial inoculum low and by following cultural practices as summarized below:

- Production of seeds from healthy crops.
- Seed treatment with 10% trisodium phosphate solution for 15-20 min.
- Minimum handling of seedlings.
- Isolation of tomato crop from other solanaceous crops, cucurbits and weeds.
- Roguing and destruction of diseased plants during early stages of growth.
- Treatment with aphicides to reduce aphid populations.

The non-implementation of these practices during several years has possibly contributed to the high incidence of virus diseases such as PVY and ToMV in Mauritius. The adoption of disease management strategies at all stages of cultivation and the use of resistant varieties are likely to bring a significant reduction in virus infection in tomato.

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STATUS OF THE SUGAR CANE SPOTTED BORER, *CHILO SACCHARIPHAGUS* BOJER (LEPIDOPTERA : PYRALIDAE: CRAMBINAE), IN MAURITIUS

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ABSTRACT

In 1996 and 1997, infestation by the spotted borer, *Chilo sacchariphagus*, in the most commonly cultivated sugar cane varieties in Mauritius was assessed in the different climatic regions. Compared to surveys conducted in 1964, 1965, 1984 and 1985 fields with higher levels of infestations were recorded. The highest infestations were in the subhumid non-irrigated zone in 1996 and in the humid non-irrigated zone in 1997. Data showed that a particular variety reacts differently to borers in different climatic regions and plant canes tend to be more susceptible than ratoons. There appears to be a relationship between percent canes bored and percent internodes bored.

Keywords: *Chilo sacchariphagus*, spotted borer, infestation, sugar cane, *Saccharum officinarum*, Mauritius.

INTRODUCTION

Chilo sacchariphagus Bojer (Lepidoptera : Pyralidae) is the most important sugar cane borer in Mauritius, while *Sesamia calamistis* Hmps. (Lepidoptera : Noctuidae), the pink borer, and *Tetramoera* (= *Argyroproce*) *schistaceana* (Sn.) (Lepidoptera : Eucosmidae), the white borer, are of lesser importance. The first serious attacks by *C. sacchariphagus* were reported in 1850 (Moutia, 1934). However, its origin is still uncertain although Vinson (1941) assumed that it originated from Java. *C. sacchariphagus* attacks mainly the soft joints within the leaf sheath.

In attempts at biocontrol, 31 species of parasitoids have been introduced (Greathead 1971; Williams 1983) but only two became established bringing the total number of primary parasitoids of *C. sacchariphagus* to six (Williams, 1983). *Cotesia flavipes* Cameron, a larval endoparasitoid, and *Trichogramma australicum* Girault, an egg parasitoid, are the most common (Ganeshan and Rajabalee, 1997). Even in cases of serious attacks by *C. sacchariphagus* insecticides are never recommended for its control. In fact, the concealed habit of the pest, the difficulty in hitting the target, and concern for the general sugar cane environment make the use of insecticides undesirable (Williams, 1983; Rajabalee, 1990). The use of sex pheromones for control by mating disruption has been explored (Nesbitt *et al*, 1980) but does not seem to be practicable.

Damage by the spotted borer, while not a constraint to sugar production island-wide, can at times be severe, causing both loss of cane weight and cane quality. Degree of infestation by the borer can be expressed as percent canes bored (% CB) and/or percent internodes bored (% IB) (Williams 1983). Bangdiwala and Martorell (1954) claimed that % IB is a more exact expression and found a linear relationship to exist between % CB and % IB during an assessment of infestation by the borer *Diatraea saccharalis* in Puerto Rico. Different sampling procedures for assessment of infestation by sugar cane borers have been proposed. Bates (1954) divided fields of six hectares into two halves and calculated the mean infestation of five samples of cane, each sample consisting of 100 stalks. Bangdiwala and Martorell (1954) assessed 100 canes at random in fields of ten acres and increased the sample size in larger fields. Hall (1986) stratified fields into 0.4 ha and assessed samples of 25 stalks each, each field being assessed more than once. In 1979 and 1982 fields of about 2.25 ha in Mauritius were intensively sampled for *Chilo* damage and Lim Shin Chong and Rajabalee (1988) proposed a sampling method for local use. Rajabalee *et al*. (1990) showed a positive correlation between the % internodes damage and sugar loss.

In Mauritius, the first exhaustive assessment of field-to-field incidence by *C. sacchariphagus* was carried out in 1964-1965 (Williams, 1983). Fields in different areas were surveyed and results showed that infestation was higher in plant canes than ratoon canes. Most of the fields surveyed had less than 20 % canes bored. A relationship between % CB and % IB was mentioned. In 1984 and 1985 (MSIRI, 1985, 1986), surveys were performed in fields of 1.5-3.5 ha, each field being divided into eight strata and data collected from four samples in each stratum, each sample consisting of 10-20 canes. In both years, infestation was highest in the sub humid unirrigated zone. Irrigated fields in the subhumid zone were less infested than unirrigated fields thereby showing the effect of humidity on the levels of borer damage. In 1985 borer infestation was compared in plant and ratoon canes and the former were found to be more infested in all zones except the superhumid zone. Since 1985, changes have occurred in the varieties cultivated as well as in cultural practices. This paper presents the results of surveys conducted in 1996 and 1997 to assess the intensity of borer damage in the different climatic regions.

MATERIALS AND METHODS

Several fields of the most commonly cultivated sugar cane varieties were surveyed for damage by the spotted borer in 1996 and 1997. Fields selected were those of mature canes near harvest. Each field was divided into eight equal strata and from each stratum four random samples were examined. Each sample consisted of 10 consecutive canes. The number of internodes and number of internodes bored per cane were recorded. The survey was conducted in all the climatic zones, i.e., subhumid (less than 1500 mm rainfall / annum); humid irrigated and unirrigated, (1500 - 2500 mm), and superhumid (> 2500 mm). The following data were also recorded : soil type, field area, date of planting for plant cane or date of previous harvest for ratoon fields, type of irrigation.

RESULTS AND DISCUSSION

The number of fields and areas surveyed for each year in the different climatic zones are given in **Table 1**, and levels of stem borer damage for 1996 and 1997 in **Figures 1& 2**. In both years the highest proportion of fields surveyed (31.9% in 1996 and 29.1% in 1997) were found to have 40-60% canes bored. For both years the highest proportion of fields had less than 5% internodes bored.

Table 1. Areas surveyed

Climatic zone	Year	No. of fields	Area ha		
			Plant cane	Ratoon	Total
Subhumid irrigated	1996	14	36	51	87
	1997	15	11	54	65
Subhumid unirrigated	1996	10	-	38	38
	1997	9	15	16	31
Humid irrigated	1996	21	17	61	78
	1997	13	19	35	54
Humid unirrigated	1996	38	38	134	172
	1997	27	39	74	113
Superhumid	1996	55	13	206	219
	1997	39	38	99	137
Total	1996	138	104	489	593
	1997	103	122	279	401

Figure 1 Stem borer damage (% canes bored)

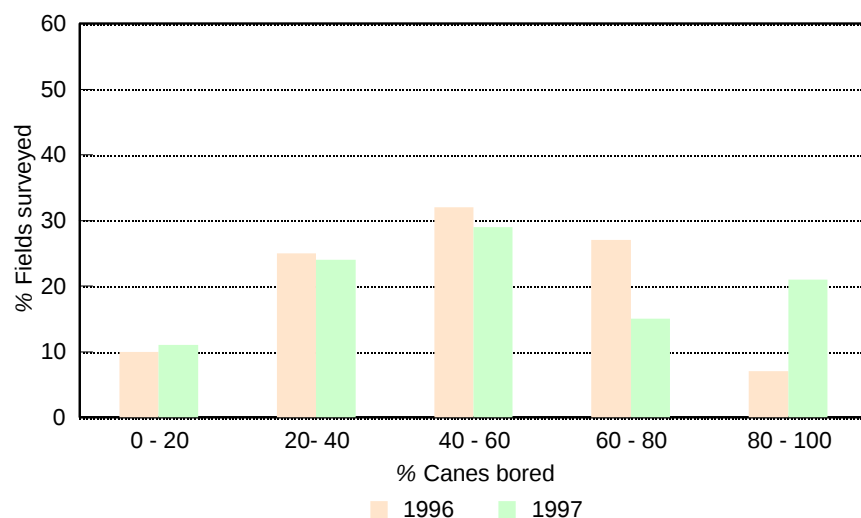
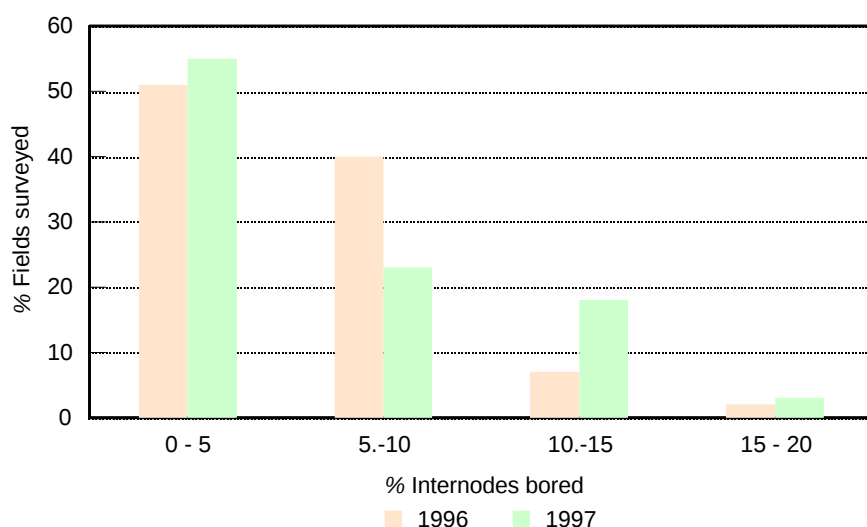


Figure 2 Stem borer damage (% internodes bored)



Tables 2 to 4 give the infestation in the different climatic regions.

Borer infestation seems to be more important in plant cane than in ratoons, with 5.87 and 5.30 % IB respectively in 1996, and 7.48 and 5.45 % IB respectively in 1997 (**Table 5**). The same tendency was observed in surveys of 1964-65 (Williams, 1983) and 1985 (MSIRI, 1986). The biochemical composition of plant canes and the disturbed environment caused by replanting might be the causes of this higher borer incidence in these fields.

Table 2 Infestation by *Chilo sacchariphagus* in the subhumid zone

Varieties	Irrigated								Unirrigated							
	1996				1997				1996				1997			
	No of fields	Area ha	% CB	% IB	No of fields	Area ha	% CB	% IB	No of fields	Area ha	% CB	% IB	No of fields	Area ha	% CB	% IB
M 555/60	2	6	59	7.0	2	4	82	10.2								
M 3035/66	2	22	37	4.7	-	-	-	-								
M 695/69	-	-	-	-	1	3	99	13.3	2	6	82	13.7	1	3	74	8.1
M 1557/70									-	-	-	-	1	2	74	9.5
M1176/77	-	-	-	-	1	4	97	12.1	-	-	-	-	1	3	92	11.8
M 261/78									-	-	-	-	2	7	20	1.8
M 1658/78	-	-	-	-	1	2	89	13.6								
R 570	10	59	54	6.0	10	53	43	4.8	8	31	56	6.9	4	16	39	5.9
Totals	14	88			15	65			10	38			9	31		
Averages			52	6.0			59	7.1			61	8.2			49	6.7

Table 3 Infestation by *Chilo sacchariphagus* in the humid zone

Varieties	Irrigated								Unirrigated							
	1996				1997				1996				1997			
	No of fields	Area ha	% CB	% IB	No of fields	Area ha	% CB	% IB	No of fields	Area ha	% CB	% IB	No of fields	Area ha	% CB	% IB
M 555/60	2	6	69	7.5	-	-	-	-	1	2	47	5.3	-	-	-	-
M 3035/66									10	40	57	5.7	5	22	72	9.1
M 695/69	2	11	30	2.8	-	-	-	-								
M 1557/70									1	2	76	9.6	1	2	93	10.9
M 1658/78	11	38	50	5.0	8	35	59	6.8	2	8	55	8.0	7	40	80	9.5
M 2350/79	-	-	-	-	1	3	88	9.9								
R 570	6	22	45	5.8	4	16	31	2.8	24	120	46	4.6	14	48	52	6.8
Totals	21	78			13	54			38	172			27	113		
Averages			49	5.3			53	5.9			50	5.2			64	8.1

Figure 3 shows the relationship between % CB and % IB from data obtained in surveys of 1996 and 1997. In both cases the relationship is a power curve of $y = 0.041x^{1.2325}$ for 1996 and $y = 0.0352x^{1.2701}$ for 1997. Thus, given the % CB of a certain field, an indication of its % IB can be obtained. As stated by Williams (1983), the amount of work in the sampling procedure could be reduced for it would only be necessary to obtain the number of canes bored in a particular field. However, more surveys will have to be performed to compare the curves of different years to confirm these results.

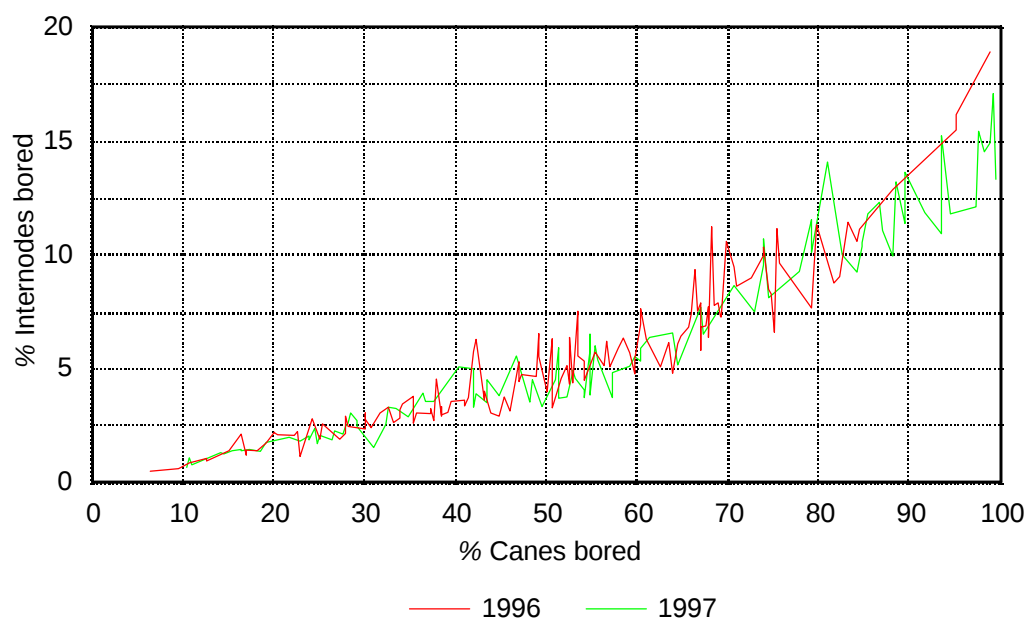
Table 4 . Infestation by *Chilo sacchariphagus* in the superhumid zone

Variety	1996				1997			
	No. of fields	Area ha	% CB	% IB	No. of fields	Area ha	% CB	% IB
M 3035/66	28	100	57	6.0	21	73	49	4.3
M 292/70	1	2	53	5.5	-	-	-	-
M 1658/78	11	58	46	4.6	14	51	39	3.9
R 570	15	60	39	2.8	4	13	33	3.2
Totals	55	220			39	137		
Averages			47	5.0			44	4.1

Table 5. Sugar cane borer infestation in plant canes and ratoons in different climatic zones in 1996 and 1997

Climatic zone	Year	Plant cane				Ratoon			
		No of fields	Area	% CB	% IB	No of fields	Area	% CB	% IB
Subhumid Irrigated	1996	7	36	56	6.0	7	51	48	5.9
	1997	4	11	89	12.1	11	54	48	5.5
Subhumid Unirrigated	1996	-	-	-	-	10	38	61	8.2
	1997	4	15	57	8.5	5	16	42	5.4
Humid Irrigated	1996	6	17	58	7.0	15	61	45	4.6
	1997	5	19	42	4.5	8	35	59	6.8
Humid Unirrigated	1996	10	38	54	5.8	28	134	48	5.0
	1997	10	39	66	9.2	17	74	63	7.5
Superhumid	1996	4	13	46	4.0	51	205	47	5.0
	1997	10	34	52	4.8	29	104	41	3.8
Totals / Averages	1996	27	104	54	5.9	111	489	48	5.3
	1997	33	118	60	7.5	70	283	50	5.4

Figure 3. Relationship between % canes bored and % internodes bored



CONCLUSION

The surveys have shown that different varieties respond differently to borer infestation in different parts of the island. The climatic conditions prevailing in a particular zone influence the borer population in that region. Humidity has been found to be one of the most important factors in limiting infestations. This fact has been confirmed not only in the subhumid zone but also in the humid zone where unirrigated fields were found to be more infested than irrigated ones. Irrigation would therefore help to reduce infestation by borers in regions of inadequate rainfall. A higher percentage of the total area under sugar cane cultivation could be assessed for borer infestation if a definite equation for the relationship between % CB and % IB could be formulated. Further studies are required to determine the loss sustained due to borer damage in varieties currently under cultivation in the different agroclimatic areas.

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THE EFFECTIVENESS OF SOME WIDELY USED ANTIHELMINTIC DRUGS ON ENDOPARASITIC NEMATODES OF VILLAGE GOATS

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Agricultural Research and Extension Unit

ABSTRACT

Gastro-intestinal parasitism could be one of the causes of deaths that led to a drastic fall in the local goat population. A recent evaluation on the level of endoparasitism in village goats in the smallholder sector was made on 39 goatherds with 588 animals from three climatic regions. It was found that 55.4 % of the herds had egg counts of above 100 eggs per gram (e.p.g) of faeces for four most common genera of nematodes namely *Haemonchus*, *Trichostrongylus*, *Strongyloides* and *Dictyocaulus*. A trial was thereafter conducted on 30 of the herds with 283 animals in order to assess their response to three commonly used anthelmintics namely: Levamisole chlorhydrate, Fenbendazole and Ivermectin. The nematocides were administered at an interval of three months and over a period of one year, and the effectiveness of each drug on the nematodes was measured and compared to control groups by the Faecal Egg Count Reduction Method. Ivermectin was found to be most effective and there was no indication of resistance build up by the parasites to the anthelmintics.

Keywords : goats, *capra hircus*, parasitoses, helminthoses, nematode infections, Mauritius.

INTRODUCTION

During the past decade the goat population in Mauritius has gone down from 72 000 heads in 1983 to 22 000 in 1993, and to an estimated 20 000 in 1996. Various factors have contributed to this drastic fall, particularly gastro-intestinal parasitism. Information on parasite species and on the epidemiology of parasitic diseases of domestic ruminants in Mauritius is scarce. Some internal parasites identified in local sheep and goats are nematodes such as *Haemonchus contortus* and *Trichostrongylus colubriformis*, and coccidia of *Eimeria* species (Sibartie unpublished data).

A Rapid Rural Appraisal, carried out by the Agricultural Research and Extension Unit (AREU.) in 1994, revealed that internal parasitism was a major problem in village goats causing heavy economic loss due to mortality and poor animal productivity. An evaluation of the level of infestation of village goats with endoparasitic nematode ova and coccidial oocysts was made in 1996 on 39 goat herds with 588 animals in the small holder sector and from regions with varying climatic conditions (Ramjee, unpublished data). Results showed that 55.4% of the goatherds passed out faeces contaminated with helminth ova with egg counts above 100 eggs per gram (e.p.g.) of faeces. Of these, 35.3% had a high infestation (> 300 e.p.g.), while 8.4% of the herds had a significantly high coccidial oocyst count (> 300 oocysts per gram of faeces). (Tables 1a and b). The common helminth parasites that were identified through faecal analysis (Benbrook and Sloss 1961) were of the genera *Haemonchus*, *Trichostrongylus*, *Strongyloides*, and *Dictyocaulus*. Coccidial oocysts were of *Eimeria* species. Gastro-intestinal nematodes like *Haemonchus*, *Trichostrongylus* and *Strongyloides* cause impaired digestion and reduced feed intake, poor productivity, and also affect mineral nutrient absorption e.g. phosphorus and possibly calcium. (Speedy 1992).

For many years, a wide range of nematocides have been used to treat against internal parasites in the smallholder sector and more commonly Benzimidazole derivatives, Fenbendazole; Imidazothiazole derivatives e.g Levamisole and Ivermectin e.g. Ivomec and Virbamec.

Table 1a Infestation of goatherds with common helminth ova and coccidial oocysts in the sub humid region

Infestation	Number of herds and % herd infestation									
	HAE		TRI		STR		DIC		COC	
	No. of herds	%	No. of herds	%	No. of herds	%	No. of herds	%	No. of herds	%
<100 e.p.g.	10	31	7	22	13	41	20	63	21	66
>100 e.p.g.	11	34	12	37	9	28	3	9	7	22
> 300 e.p.g.	11	35	13	41	10	31	9	28	4	12
Total	32	100	32	100	32	100	32	100	32	100

HAE-Haemonchus; TRI-Trichostrongylus; STR-Strongyloides; DIC-Dictyocaulus; COC-Coccidia
 Total number of goats involved = 543 Herd size = 5 to 53 heads
 Source : RAMJEE (unpublished data.)

Table 1b Infestation of goat herds with common helminths ova and coccidial oocysts in the humid and super humid regions

Infestation	Number of herds and % herd infestation							
	HAE		TRI		STR		COC	
	No. of herds	%	No. of herds	%	No. of herds	%	No. of herds	%
<100 e.p.g.	2	29	2	30	2	28	2	26
>100 e.p.g.	3	37	2	35	2	32	3	44
> 300 e.p.g.	2	34	3	35	3	40	2	30
Total	7	100	7	100	7	100	7	100

HAE-Haemonchus; TRI-Trichostrongylus; STR-Strongyloides; COC-Coccidia
 Total number of goats involved = 45 Herd size = 4 to 13 heads
 Source : RAMJEE (unpublished data.)

These nematocides have been found to give satisfactory control against all parasitic stages of the nematodes, although they differ in their action on the various stages of the life cycle of the different parasites. However these have not been used in a planned manner for the control of endoparasitic nematodes in the smallholder sector. Therefore, the capability of the goats to resist infection and any anthelmintic resistance by the parasites is not known. A study was therefore undertaken to compare the effectiveness of three commonly used anthelmintics in selected smallholder goatherds.

MATERIALS AND METHODS

30 goat herds comprising 283 animals from sub humid (annual rainfall < 1250 mm), humid (1500-2500 mm) and super humid (> 2500 mm) regions were selected from the 39 herds previously surveyed. The treatment aimed at controlling the four common genera of endoparasitic nematodes identified, through the administration of three widely used and locally available anthelmintic drugs (Bolumisole 1, Panacur 2.5% and Virbamec), and a control. The four treatments were allocated randomly to the 30 herds which were divided into 3 main groups (sub humid, humid, and superhumid), as given in (Table 2). The number of animals per herd ranged from 6 to 78 with an average of 9.4 head per herd. The trial started in June 1996 and lasted one year.

Table 2. Distribution of treatment groups and control

GROUP	Anthelmintic Treatment						Control		Total	
	Bolumisole		Panacur		Virbamec					
	herds	goats	herds	goats	Herds	goats	Herds	goats	Herds	goats
Sub Humid	3	31	3	44	2	30	3	40	11	145
Humid	2	10	2	8	2	8	1	6	7	32
Super Humid	3	16	3	26	3	37	3	27	12	106
Total	8	57	8	78	7	75	7	73	30	283

EXPERIMENTAL INVESTIGATION

Treatment with anthelmintics

Anthelmintic treatment was given as per recommended route on liveweight basis, in the morning before feeding. **Table 3.** Each treatment for respective groups was given at a regular interval of 3 months, after weighing of animals to determine the correct dosage. Pregnant does were not weighed and kids under one month of age were not treated.

Table 3 Treatment with anthelmintics

Trade Name	Active Ingredient	formulation	Route	Dosage
Bolumisole 1*	Levamisole Chlorhydrate 0.3g / bolus	Bolus1 g	Oral	¼ bolus for 612 kg liveweight
Panacur2.5%* *	Fenbendazole 2.5g / 100cc	Aqueous Suspension	Oral	2cc / 10 kg liveweight
Virbamec***	Ivermectin 1% m / v	Solution	Injection S / C	0.5cc / 25kg liveweight

* Bolumisole 1 - Laprovet Lab., B. P. 2262-37022 Tours CEDEX, France

** Panacur 2.5% - Distrivet Lab., 163, Ave. Gambetta, 75020 Paris

*** Virbamec - Virbac do Brasil Industries e Comercio Ltda, Rua Humberto 1,220, 10 andar - CEP 04018 - 030
SAO PAULO, BRAZIL

Faecal egg count

Fresh faecal samples for each herd were collected per rectum and from the ground prior to each drug administration, as given below:

Goats	Samples
1 to 5	3
5 to 10	6
10 to 15	9
> 15	12

Samples collected for each herd were homogeneously mixed and 3 sub samples taken for egg count. The Mac Master Technique (flotation in a known volume of saturated salt solution in a special slide with a 'Mac-Master' chamber) (Troncy, Itard and Morel 1981) was used for faecal egg count (FEC). Counts were recorded separately for each of the genera *Trichostrongylus* (TRI), *Haemonchus* (HAE), *Strongyloides* (STR) and *Dictyocaulus* (DIC) respectively. Counts obtained were rounded to the nearest hundred and any count occurring below hundred was considered as 'no infection'. Reduction in faecal egg count (FECD) was actually used as a measure for the effectiveness of the three anthelmintic drugs.

RESULTS

Faecal egg count reduction

The FECR obtained 3 months after each anthelmintic treatment is given in **Table 4** for each of the genera of TRI, HAE, DIC and STR. The FEC was considerably reduced in all 3 treatment groups following anthelmintic treatment, whereas there was reinfestation in the control. It was found that Virbamec was most effective against the four genera of nematodes, followed by Panacur and Bolumisole.

Table 4 Faecal egg count reduction at three months interval

Treatment	% FECR*							
	<i>Trichostrongylus</i>				<i>Haemonchus</i>			
	Months after treatment							
	3	6	9	12	3	6	9	12
Control	18	2	N.A	68	29	27	N.A	50
Bolumisole	71	79	100	100	88	84	66	85
Panacur	40	100	100	100	80	80	100	80
Virbamec	100	100	100	100	50	75	75	100

Treatment	% FECR							
	<i>Dictyocaulus</i>				<i>Strongyloides</i>			
	Months after treatment							
	3	6	9	12	3	6	9	12
Control	75	75	NA	12	75	75	NA	12
Bolumisole	0	59	100	100	50	31	100	100
Panacur	80	100	100	100	53	61	100	100
Virbamec	50	66	100	33	NA	100	100	100

* Larval count for *Dictyocaulus*

Effectiveness of the three anthelmintics

The effectiveness of the 3 drugs on each of the nematodes can be summarised as follows: -

Drug	Decreasing order of effectiveness			
Virbamec	TRI	STR	DIC	HAE
Panacur	TRI	DIC	STR	HAE
Bolumisole	TRI	DIC	STR	HAE

Resistance of the helminth parasites to the anthelmintics

There was no indication of resistance to any of the three anthelmintics administered, based on the FECR. The FEC prior to treatment ranged from 264 e.p.g. to 907 e.p.g. for all treatment groups combined, whereas the FECR following anthelmintic treatment was considerably reduced in the range of 0 to 300 e.p.g..

DISCUSSION

Infestation with helminth parasites in different climatic regions

The survey conducted prior to the trial revealed that in 35.3% of the infected herds there was a high infestation of above 300 e.p.g. This high infestation was prevalent in all the three climatic regions in sheds, which harboured high humidity due to leaking roofs and stacking of fodder and manure. These conditions enhanced a low level of hygiene and favoured reinfestation. This was confirmed during the trial, irrespective of the climatic region. Reinfestation was much lower in sheds where manure was removed regularly, fodder was not stacked and the floor was kept relatively dry.

Immune response of the goats to helminth infection

Hosts regulate parasites by acquired immunity following continued exposure to these and their antigens, and the development of immunity is influenced by age, nutritional status, pregnancy and lactation (Speedy, 1992). In the control, faecal egg counts at the start of the trial were in the range of 166 to 514 epg, while for the rest of the 12 months period they were 0 to 450. This indicates that the goats have a capacity to regulate the parasites through acquired immunity.

Choice of drugs for effective control

All the 3 drugs are recommended by their respective manufacturers for the control of both gastro-intestinal and lung parasites, and on mature as well as immature stages of the nematodes. However the FECR indicated that alternating Virbamec with Panacur could give better control of the nematodes, thereby avoiding build up of resistance.

Development and detection of anthelmintic resistance

Some of the factors that favour nematodes to develop resistance to anthelmintics are wrong timing of treatments, underdosing with anthelmintics and underestimation of liveweight of animals (Speedy, 1992). In the trial, treatment was given every three months and on a liveweight basis. One of the methods used to detect anthelmintic resistance is by the FECR test, and interpretation of FECR depends on the time lapse between drug administration and collection of faeces for egg count (Speedy, 1992). In the trial, egg counts were made prior to drug administration and three months after administration. Results of FECR obtained indicated that both the development and the detection of anthelmintic resistance were effectively tested.

Cost of controlling the helminth parasites

An economic analysis for the control of helminth parasites in the smallholder sector is given in **Table 5**. In one year, 4 treatments with Virbamec (one treatment every 45 days) alternated by 2 treatments with Panacur (one treatment every 3 months) would presently cost around Rs 266 for an average herd of 9.4 goats (average sized farm). This amounts to two thirds of the cost of 7 treatments with Virbamec alone.

Table 5 Medication cost for the control of helminth parasites

Anthelmintic	Dose	Wt. of goat kg	Cost per treatment Rs	Treatments year ⁻¹	Cost animal ⁻¹ year ⁻¹	Cost farm ⁻¹ year ⁻¹ (Ave: 9.4 goats)
Virbamec	0.5 cc	25	6.03	7	42.21	397
Panacur	50cc	25	2.10	4	8.40	79
Bolomisol	½ Bolus	25	1.92	4	7.70	73

CONCLUSION

All the three commonly used anthelmintics provide effective control of the endoparasitic nematodes if administered every 3 months. Though Virbamec was more effective, it was more expensive and not fully practical for farmers in the smallholder sector since it had to be injected subcutaneously. Although no anthelmintic resistance by the nematodes was observed, alternating any of the 3 drugs would provide a more efficient control of the parasites avoiding development of resistance.

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PROTEIN SUPPLEMENTATION OF RUSA HINDS (CERVUS TIMORENSIS RUSSA) ON THE PERFORMANCE OF FAWNS

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ABSTRACT

Grazing hinds are normally fed with a maintenance ration. The effect of supplementation with cotton seed cake in addition to the normal practice during late pregnancy and early lactation on the performance of fawns was evaluated using sixty pregnant hinds aged 3 to 4 years. The hinds were of similar body condition. No significant effect was observed between treatments for both birth weight and growth weight of fawns.

Keywords : *Cervus timorensis russa*, rusa deer, feed supplements, late-pregnancy, lactation, cottonseed, oilseed cakes, concentrates, performance, Mauritius.

INTRODUCTION

The objective of any meat production system in a commercial farm is the production of a desired carcass weight in the shortest period of time. The most efficient means of achieving this objective in rusa deer is to create conditions to ensure that fawns do not experience any form of stress and are allowed to grow steadily to target weights of over 45 kg in about 15 months. At this age, males are ready for slaughter whilst females are ready for breeding.

Generally hinds have to meet their peak nutritional demands during lactation (Denholm 1989). In the western part of Mauritius, where the annual rainfall is often less than 750 mm, this peak occurs between April and June at a time when hinds are often grazing on mature, dry pasture with declining digestibility and protein content. Peak milk production and the lactation curve are both affected by nutrition in cervids (White 1991). In the pre-ruminant stage of development, the growth of fawns is highly dependent on an adequate milk supply (Loudon and Kay 1984, cited by White 1991). In the pre-ruminant fawn milk nutrients are used for both maintenance and growth. As the rumen develops in the young fawn, milk nutrients are used with maximum efficiency for growth while rumen metabolites are used to meet maintenance requirements White (1991). Hence in situations where food quality declines, the level of milk intake may be critical to maintain a high growth rate of fawns. Strategic feeding of hinds with supplements containing high quality dietary protein may, therefore, be necessary to maximise milk production when pastures are inadequate

OBJECTIVE

The present study has been undertaken to determine the effects of feeding a protein supplement to grazing hinds during late pregnancy and early lactation on fawn birthweight, growth rate till weaning and mortality. Cotton seed cake was used as the supplement.

MATERIALS AND METHODS

The study was conducted at the Magenta Deer Farm of Medine Sugar Estate. The experiment started on 19th March 1997 and was completed on 9th October 1997.

Experimental animals

Sixty pregnant hinds (*Cervus timorensis russa*) aged 3 to 4 years and of about the same body condition were drawn from a herd containing approximately 755 hinds. After weighing, the hinds were randomly allocated to 2 groups of 30 animals each. Each group was then assigned randomly to one of two treatments, namely with cotton seed cake supplementation and no supplementation control.

Feeding

The 2 herds were run separately by rotating through a series of four 1.8-hectare paddocks. The basic diet for all the hinds consisted of star grass (*Cynodon plectostachyus*) pasture and 400g per head per day of a farm-made mixture known as “melabag”. The pasture had a drymatter (DM) content of 44.2 %, a crude protein CP of 8.1% and contained about 9,300 kg DM per hectare at the time of introduction of animals. The melabag contained sugar-cane molasses, wheat bran and poultry litter as the main constituents and had the following approximate composition: DM: 57.6%, CP: 14.2%, crude fibre (CF): 13.2%, ether extract (EE): 1.3% and Ash: 10.0%. Feeding of melabag is a normal practice on this farm. Water was provided ad libitum.

The supplemented group was fed 200g of cotton seed cake per head per day. The supplement was provided on alternate days during late pregnancy and early lactation (from 5 weeks pre-fawning till 6 weeks after fawn drop). The supplement was offered in troughs, which provided adequate feeding space for each hind.

Monitoring of fawning

From the time the first hind fawned, all hinds were inspected twice daily (morning and afternoon), to record births. The fawns were picked up, tagged, weighed and their sex determined within 24 hours after birth. They were then put back where they had been found.

Post-natal fawn growth

Fawns were weighed at birth and at approximately 8, 17 and 21 weeks post-partum. Growth rates were then calculated, enabling the estimation of weight at given ages (WGA) at 60, 120 and 150 days

Statistical analyses

Observed means were compared using Student's t test. Only data from fawns born during the peak fawning period (4th to 25th May 1997) have been considered because almost 70% of the fawns were born in that period.

RESULTS

Fawning and neo-natal mortality

The first fawn drop occurred on 23rd April 1997 and fawning continued over a period of 73 days. The fawning pattern is shown in (Figure 1). 56 out of the 60 hinds fawned giving an overall fawning rate of 93%. 30 males and 26 females were born. Two females fawn died the control and one in the treatment group. The weaning rate, calculated as $100 \times (\text{number of weaned fawns} / \text{number of live fawns at 24 hours})$, was 95% and the male/female ratio was 1.2:1 (Table 1).

Figure 1 Fawning pattern over a period of 73 days

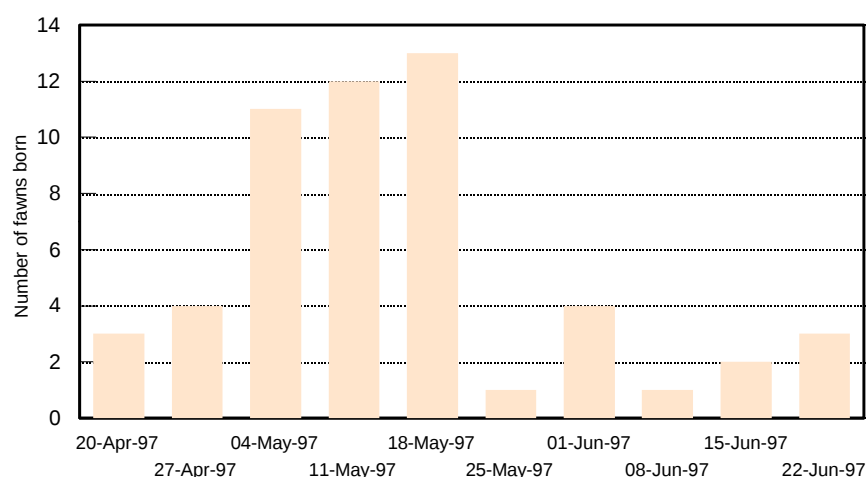


Table 1 Fawning and weaning rates for the two groups of rusa hinds

Parameter	Supplemented	Control	Total
Number of hinds	30	30	60
Fawning rate (%)	93	93	93
Male / Female fawns (%)	64/36	43/57	54/46
Pre-weaning mortality (%)	7.1	3.6	5.4
Weaning rate (%)	96	93	95

Birth weight

The mean weight of female fawns at birth was 5.3 ± 0.7 kg, while that of males was slightly higher (5.6 ± 0.6) but not significantly different (Table 2). There was no significant difference between the two groups.

Table 2 Weight (kg) of newborn rusa fawns according to sex and treatment groups.

Parameter	Female	Male	Supplemented	Control
Number of fawns	14	21	17	18
Mean weight	5.3	5.6	5.5	5.5
Standard Deviation $\pm$	0.7	0.6	0.6	0.7
Range	4.0 - 6.5	4.5 - 7.0	4.0 - 7.0	4.5 - 7.0

Fawn growth from birth to weaning

Fawns were weaned at a mean age of 21 weeks and the weaning rate was 95%. The proportion of weaned males was 100% and that of females was 88%.

The overall average daily growth, regardless of sex and treatment group, was 215 ± 31 g from 0 to 56 days, 139 ± 18 g from 56 to 119 days, 74 ± 21 g from 119 to 147 days and 155 ± 19 g from birth to 147 days (**Table 3**).

Table 3 Average daily weight gain (ADG, g / d $\pm$ S.D) of rusa fawns according to sex and treatment group.

	Female	Male	Supplemented	Control	Total / Averages
Number of fawns	12	21	16	17	33
ADG (0 - 56 days)	198 ± 33^a	225 ± 26^a	222 ± 31	209 ± 31	215 ± 31
ADG(56-119 days)	125 ± 12^b	147 ± 15^b	148 ± 16^c	131 ± 15^c	139 ± 18
ADG (119 -147 days)	66 ± 17	78 ± 22	75 ± 25	73 ± 18	74 ± 21
ADG (0 - 147 days)	141 ± 15^d	163 ± 16^d	161 ± 19	149 ± 17	155 ± 19

a,b,c,d Difference between groups were significant ($p < 0.05$)

Figures with different superscripts within the same row are significantly different ($P < 0.05$) At the beginning of the suckling period (0 - 56 days) fawns from the 2 groups of hinds had similar average daily weight gain. However, during the period 56 to 119 days fawns from supplemented hinds grew significantly ($P < 0.05$) faster than those of unsupplemented hinds. Whereas, prior to weaning (119 - 147 days) there was again no difference in growth rate of fawns in the two groups.

From birth to 56 days and from 56 to 119 days the growth rate of males was significantly higher ($P < 0.05$) than that of females. However there was no significant difference due to sex from 119 to 147 days.

The growth rate figures were used to calculate weight of fawns at given age. At 60, 120 and 150 days the respective weights were 18 ± 2 , 27 ± 2 , and 29 ± 3 kg (**Table 4**).

Table 4 Weight at given age (WGA, kg $\pm$ S.D) of rusa fawns according to sex and treatment.

Parameter	Age days	Female	Male	Supplemented	Control	Total / Averages
Number of fawns		12	21	16	17	33
WGA	60	17 ± 2	19 ± 2	19 ± 2	18 ± 2	18 ± 2
WGA	120	25 ± 3	28 ± 2	28 ± 3	26 ± 3	27 ± 3
WGA	150	27 ± 3	30 ± 3	30 ± 3	28 ± 3	29 ± 3

There was a significant effect ($P < 0.05$) of sex on weight of fawns at 60, 120 and 150 days with male fawns having higher weights than female fawns. There was no significant effect of treatment on weight at given age.

DISCUSSION

Recording of weight at birth

Weighing of fawns is not a management practice among deer farmers in Mauritius for fear of problems related to maternal rejection. However, this study has shown that careful handling and weighing of fawns does not lead to a disruption of hind to fawn relationship. No case of maternal rejection or stress on fawns was observed during this trial.

In this study, the average weight of rusa fawns at birth was 5.6 kg for males and 5.3 kg for females. These figures are higher than those recorded elsewhere. For example, Woodford and Dunning (1991)

reported weights at birth for Javan rusa deer of 5.1 kg for males and 4.7 kg for females in Queensland, Australia. In the study of Le Bel et al (1997), the average birth weights of Javan rusa fawns in New Caledonia were 3.6 kg for males and 3.5 for females.

The birthweight of fawns on a farm gives an indication of the level of management practised on the farm. Birth weights of fawns recorded at Palmar Livestock Production Unit (unpublished data) were comparable to those obtained in this study. The magnitude of these weights is higher than the figures usually quoted (3.5 to 4.5 kg) by traditional deer farmers in Mauritius (Personal communications).

Mortality

All the 56 fawns were strong and healthy in the 24 hours following birth. Three fawns died during the pre-weaning period giving an overall mortality rate of 5%. Deaths occurred as a result of starvation in one case (the fawn had crossed the fence but could not come back) severe tick infestation in the second case and to the fawn being caught in the fence in the third case. A higher mortality rate (10 to 20%) is usually experienced on most commercial farms (Personal communications).

Growth and weaning

In the current experiment, the weaning rate at 21 weeks was 95%. For Javan rusa deer Le Bel et al (1997) recorded a weaning rate of 84% at 18 - 23 weeks in New Caledonia. Woodford and Dunning (1991), in Queensland, Australia reported a similar rate to that found in this experiment.

In this experiment fawn growth until weaning was on average 155 g per day. However, for Javan rusa fawns, Le Bel et al (1997) recorded an average growth rate of 124 g per day on pasture. Woodford and Dunning (1991) observed a similar growth rate of 158 to 172 g per day for the same species under intensive farming conditions. The contribution of melabag in the basal diet of the hinds cannot be overlooked, especially in terms of its contribution as a source of crude protein (CP: 14.2%). It would appear that melabag-supplied part of the nutrients that could have been deficient in the pasture to allow the hinds and fawns to attain growth rates close to their potential. Therefore the contribution of cotton seed cake in this trial had little effect.

Loudon and Milne (1985) working with red deer found that calf (young of red deer) growth rates were significantly correlated with milk yield over a lactation period of 100 days. At the initial stage of lactation a high growth rate was obtained. Beyond 30 days of lactation calves grew at a consistently slower rate. In the current experiment, the weight gain of fawns followed the same trend. It therefore appears that the decline in milk yield in the last stages of lactation could not sustain a high growth rate of fawns.

CONCLUSION

Supplementation of hinds from 5 weeks pre-fawning till 6 weeks after fawn drop using 200 g cotton seed cake per head per day did not significantly increase fawn birthweight and fawn growth rate till weaning. This demonstrates that feeding a protein rich supplement to hinds during late pregnancy and early lactation is not necessary if nutrition from the basic diet is already adequate. The birth weight of the fawns was good and weaning rate at 21 weeks was 95%. Mortality rate also was acceptable at 5%. Careful weighing and handling of the fawns did not lead to maternal rejection of fawns or undue stress on them. It is possible that response to short term supplementation may occur if hinds are exposed to grazing conditions that are poorer than those in this study. Further experimental work is therefore required to define the nature and level of supplementation necessary under conditions of poor pasture herbage availability and quality.

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STUDY OF GENETIC DIVERSITY IN A RUSA DEER (*CERVUS TIMORENSIS RUSSA*) POPULATION IN MAURITIUS USING DERIVED BOVINE MICROSATELLITES

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CIRAD and Deer Farming Cooperative

ABSTRACT

*Bovine microsatellite systems were used to amplify rusa deer (*Cervus timorensis russa*) DNA. Nine markers, (ABS12, BM2934, CSSM041, IDVGA55, ILSTS006, INRA040, TGLA57, TGLA122, TGLA126) showing different polymorphisms in bovine and other deer species (red, sika) were tested. Seven markers gave PCR amplification products of which 3 were polymorphic. There was no amplification for CSSM041 and ILSTS006. These are the first results obtained in a rusa deer population completing previous studies on various deer species.*

Keywords : *Cervus timorensis russa*, microsatellites, PCR, polymorphism, rusa deer, genetic-diversity, Mauritius.

INTRODUCTION

Microsatellite loci are often conserved among related species. This conservation has been shown in various species such as cattle and sheep (Moore et al. 1992), humans and chimpanzees (Deka et al 1994) or dog and fox (Fredholm and Winters 1995). Multi-allelic microsatellite systems are therefore very powerful for most population genetics, linkage mapping and parentage studies (Bruford and Wayne 1993 ; Jarne and Lagoda 1996).

Transfer of bovine microsatellites between families of the *artiodactyla* order has been demonstrated several times (Slate et al. 1998 ; Kuhn et al 1996 ; Engel et al 1996).

MATERIALS AND METHODS

Animal population

Sampled deers are originated from 7 farms (Medine sugar estate, Sovil, Bel Ombre sugar estate, Baie du cap Deer Farming, Société RPA de Ravel, Beau Champ sugar estate, Constance et la Gaieté sugar estate Co Ltd) located on the west and east coasts of the island. All the farmers are members of the Mauritius Deer Farming Co-operative Society Ltd.

Collection of samples

Blood samples from 110 rusa deer of both sexes and different ages were collected in EDTA vacutainers.

DNA extraction

Purified genomic DNA was extracted from white blood cells using the Promega Wizard™ Genomic DNA Purification Kit.

Markers tested

Bovine microsatellites known to amplify red (*Cervus elaphus*) and sika (*Cervus nippon*) deer were used. Nine markers showing a high polymorphism level for both species were selected (Slate et al. 1998).

PCR protocol

Twenty-five (25) ng of DNA were used in 25µl PCR-reaction with 0,2 µM of each primer, 200 µM of each DNTP, 2 mM MgCl₂, 2,5 µl GeneAmp 10X PCR Buffer (Perkin Elmer), 1UI of *Taq* polymerase (Ampli*Taq* Gold, Perkin Elmer).

PCR amplification was performed as follows: 12 min denaturation step at 94 °C (hot start); 35 cycles of 1 min denaturation at 94°C, 1 min at annealing temperature, 1 min extension at 72°C. The final elongation step was extended to 10 min.

PCR amplification products were migrated on 4 % ethidium bromide stained agarose gels (Metaphor). After electrophoresis (80 volts, 2 hours), the gels are visualised on an UV-light transilluminator. Photographs are taken and used for the allele discrimination.

RESULTS

The results obtained for these polymorphic loci are summarised in **Table 1**. Cattle chromosomal locations, size of alleles in cattle and number of alleles found in Rusa deer are compared.

Table 1 Polymorphic loci results

Microsatellite marker	Bovine		Annealing Temp °C	Alleles in Rusa deer		Reference
	chromosome location	Allele size (bp)		numbers	Estimated size	
TGLA 57	1	80-104	55	3	88-90	Georges and Massey, 1992
INRA40	2	205-230	65	4	200-240	Vaiman et al., 1994
ABS12	26	-	55	7	139-163	Pfister-Genskow et al., 1995

DISCUSSION

These preliminary results confirm that microsatellites can be transferred between families of the *artiodactyla* order. The microsatellite systems used in our study had previously successfully amplified red and sika deer DNA (Slate et al. 1998) Rusa deer DNA can now be added to the list.

The identification of rusa deer microsatellite systems sets up the first basis of Mauritius Rusa deer genetic investigations. The results that will follow this study may lead to an enhancement of Rusa deer farming in Mauritius by the proposal of efficient breeding schemes. Furthermore, microsatellite systems could be applied in New-Caledonia, Australia or Réunion Island allowing comparisons between other Rusa deer populations.

ACKNOWLEDGEMENTS

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OCCURRENCE OF CORAL BLEACHING IN THE MARINE PARKS OF MAURITIUS

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ABSTRACT

Coral bleaching was observed in the Balaclava and Blue Bay Marine Parks. The bleaching process started in late February 1998. The extent of coral bleaching and its effects on the ecosystem are presented and discussed. The possible causes leading to bleaching of corals have also been investigated. The occurrence of coral bleaching is more pronounced in the lagoonal patch reefs and the back reefs than in the fore reef of the fringing reefs. 39% and 31% of live corals were affected by bleaching in the lagoons of Balaclava and Blue Bay marine parks respectively.

Keywords: coral-bleaching, marine environment, marine-parks, line intercept transect, Mauritius.

INTRODUCTION

Coral bleaching is the whitening of coral colonies due to the loss of symbiotic zooxanthellae from the tissues of polyps. This loss exposes the white calcium carbonate skeleton of the coral colony. Corals naturally lose less than 0.1% of their zooxanthellae during processes of regulation and replacement (Brown and Ogden 1993). However, adverse changes in a coral's environment can cause up to 80% loss of zooxanthellae. There are a number of stresses or environmental changes that may cause bleaching including diseases, excess shade, increased levels of ultraviolet radiation, sedimentation, pollution, salinity changes and increased temperatures.

In Mauritius coral bleaching has been observed in the lagoonal patch reefs, the back reefs and to a lesser extent in the fore reefs in late February 1998, a period which has coincided with abnormally high air temperatures and heavy rainfall. Coral bleaching has been studied in the lagoons of the Balaclava and Blue Bay marine parks.

METHODOLOGY

The Line Intercept Transect (LIT) technique was used to estimate the extent of coral bleaching. LIT technique was developed in terrestrial plant ecology and subsequently adopted by coral reef ecologists. The procedure fuses a classification system based on structural attributes of life forms rather than species level data. The LIT is used to estimate the cover of an object or group of objects within a specified area by calculating the fraction of the length of the line that is intercepted by the object. This measure of cover, usually expressed as a percentage (English et al 1997), is considered to be an unbiased estimate of the proportion of the total area covered by that object if the following assumption apply: that the size of the object is small relative to the length of the line and that the length of the line is small relative to the area of interest.

Six study stations were selected in the lagoon of each marine park. At each station 30m long transects were set along the four cardinal points. A diver usually lays a 30m transect tape from a star picket in the northerly direction. Another diver records the coral data using life-form categories on an underwater slate. The transect tape is then rotated around the star picket in the easterly, southerly and western directions and observations noted. The diver is equipped with either snorkelling or scuba gear depending on the water depth at each of the stations. The state of the corals are recorded as unbleached-UB, partly bleached-PB (<50% of the colony), bleached-B (>50% of the colony) and dead-D. The

present study covers the period from March to May 1998. The life form categories for corals (English et al 1997) encountered in the marine parks along with their codes are presented in Table 1.

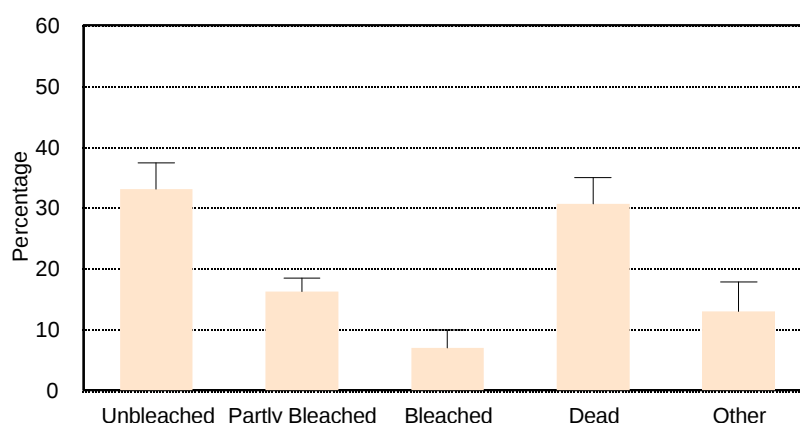
Table 1 Life-form categories and codes

CATEGORIES	CODE	NOTE / REMARKS
Dead Coral	DC	Recently dead, white to dirty white
Acropora Branching	ACB	At least 2 branching, e.g. <i>A. palmata</i> and <i>A. formosa</i>
Acropora Submassive	ACS	Robust with knob or wedge-like form e.g. <i>A. palifera</i>
Acropora Digitate	ACD	No. 2 branching, typically includes <i>A. humilis</i> , <i>A. digitifera</i> and <i>A. gemmifera</i>
Acropora Tabular	ACT	Horizontal flattened plates e.g. <i>A. hyacinthus</i>
Encrusting coral	CE	Major portion attached to substratum as a laminar plate e.g. <i>Porites vauhani</i> , <i>Montipora undata</i>
Foliose	CF	Coral attached at one or more points, leaf-like, or plate-like appearance e.g. <i>Merulina ampliata</i> , <i>Montipora aequituberculata</i>
Massive	CM	Solid boulder or mound e.g. <i>Platgyra daedalea</i>
Mushroom	CMR	Solitary, free-living corals of the <i>Fungia</i>
Others	OT	Other benthos

OBSERVATIONS

The lagoon in Balaclava Marine Park had a coral cover of 87 ± 4.8 %, whilst other benthos comprised 13 ± 4.7 %. **Figure 1** depicts the percentage substrate cover in terms of unbleached, partly bleached, bleached, dead corals and other benthos. Dead corals had a cover of 30.7 ± 4.3 % and live coral cover represented 56.3 ± 3.4 %. Partly bleached and bleached corals had a cover of 16.2 ± 2.2 % and 7 ± 2.9 %. **Plate 1** shows some partly bleached and bleached corals at Balaclava.

Figure1 Percentage substrate cover in Balaclava Marine Park



The live coral cover comprised the following life-form categories:

ACB	CF	ACT	CM	ACD	ACS	CMR	CE
68.8%	18.7%	5.5%	5.4%	1.1%	0.3%	0.3%	0.1%

Plate 1 Partly bleached and bleached corals at Balaclava

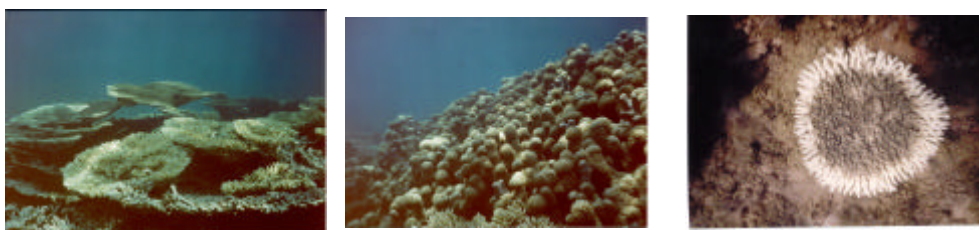
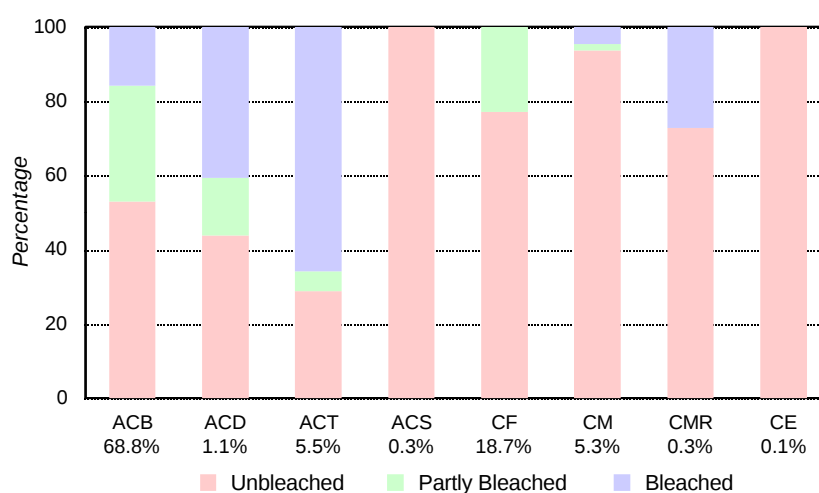


Figure 2 depicts the bleaching effect on the different coral types. Four types of corals were bleached namely:

Tabular <i>Acropora</i>	Digitate <i>Acropora</i>	Branching <i>Acropora</i>	Massive corals
65.9%	40.6%	15.9%	1.9%.

Foliose corals were partly bleached up to 22.8%. The coral form, which showed highest partial bleaching, was branching *Acropora* (31.1%).

Figure 2 Life form category coral bleaching at Balaclava



In the lagoonal areas of the Blue Bay Marine Park, the coral cover was 88 ± 1 %, whilst other benthos comprised 12 ± 1 %. Live coral cover represented 73.6 ± 2.7 % and dead corals 14.3 ± 2.4 %.

Figure 3 depicts the percentage substrate cover in terms of unbleached, partly bleached, bleached, dead corals and other benthos. Partly bleached corals had a cover of 20.9 ± 4.2 % and bleached corals represented 2.8 ± 0.9 %. **Plate 2** shows some bleached and partly bleached corals at Blue Bay.

Plate 2 Partly bleached and bleached corals at Blue Bay



Figure 3: Percentage substrate cover in Blue Bay Marine Park

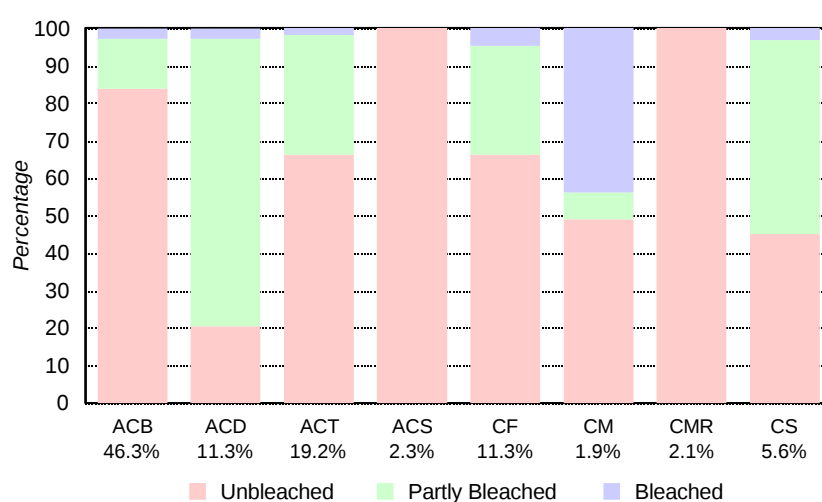


The coral life form categories under live cover were

Branching <i>Acropora</i>	Tabular <i>Acropora</i>	Digitate <i>Acropora</i>	Foliose corals	Submassive corals	Submassive <i>Acropora</i>	Mushroom corals	Massive corals
46.3%	19.2%	11.3%	11.3%	5.6%	2.3%	2.1%	1.9%

The bleaching effect on the different types of corals is shown in **Figure 4**.

Figure 4 Life form category coral bleaching at Blue Bay



Massive corals were bleached to an extent of 43.9% whilst bleaching of other coral forms was less than 5%. Partial bleaching was most pronounced in digitate *Acropora* (77.9%), followed by submassive corals (51.9%), tabular *Acropora* (32%) and foliose coral (30%).

DISCUSSION

The live coral cover in the lagoons of Balaclava and Blue Bay Marine Parks had been bleached to an extent of 12% and 4% respectively. However, partial bleaching in both the marine parks was to the extent of 27%. Thus bleaching affected 39% and 31% of the live corals in Balaclava and Blue Bay respectively.

Coral bleaching occurs in response to a wide range of stresses. It is a frequent symptom of pollution induced stress, as well as a response to natural factors such as changes in water temperature, salinity levels and possibly elevated ultraviolet light (Brown 1993). The possible causes of bleaching may be attributed to one or a combination of the following factors: high temperature, excessive rainfall, reduced salinity, high turbidity.

Corals tolerate a narrow temperature range between 25oC and 29oC depending on location. Corals bleach in response to prolonged temperature change and not due to rapidly fluctuating temperatures. Laboratory experiments show that corals bleach when water reaches a constant 32oC (Brown and Ogden 1993).

Satellite derived sea surface temperatures (SSTs) have been used to identify the areal extent of coral reef bleaching. SSTs are being routinely obtained from satellites operated by the U.S. National Oceanic and Atmospheric Administration (NOAA). These measurements are obtained both day and night from the Advanced Very High Resolution Radiometer (AVHRR) on all NOAA's polar satellites and, therefore, permit coverage of all oceans (Strong 1992). Whenever positive SST anomalies occur during the warmest months of the year, often a 1oC elevation above the maximum monthly mean accompanies bleaching (Strong et al 1996).

Coral bleaching triggered by warm temperatures became a frequent problem as from the 1980's. Worldwide bleaching of corals (with as much as 60% death on some Indo-Pacific reefs) had been observed since 1985. During the 1997-98 El Nino, NOAA has confirmed coral bleaching in the Western Hemisphere at sites in the Florida Keys, Baja California, and Pacific Coast of Panama, the Yucatan Coast, Caymans and the Netherlands Antilles. In the Eastern Hemisphere, reefs in the Red Sea and the Seychelles have experienced some bleaching during the past year (ANON 1998).

Using satellite derived sea surface temperatures (SST), (Strong and Duda 1997) have extrapolated that during the warmest months a 1oC elevation above the maximum monthly mean caused coral bleaching. SST data for Mauritius received from NOAA's satellite by ORSTOM-SEAS receiving station in La Reunion were in the range of 27-28oC for the months of January to March for the years 1996, 1997 and 1998. The monthly maximum mean for SST was not available. However, the sea surface temperature recorded by the wave-rider buoy installed by the meteorological services off Blue Bay (outside the lagoon) gave a monthly mean of 28.4 oC with a monthly maximum of 29.0 oC in February 1998. The sea surface temperatures recorded off Blue Bay are presented in (Table 2).

Table 2 Monthly sea surface temperatures °C off Blue Bay

	1997		1998	
	Mean	Max.	Mean	Max.
January	-	-	-	-
February	-	-	28.4	29.0
March	27.5	27.9	28.1	28.9
April	26.9	27.8	27.3	27.9
May	26.2	27.1	26.0	26.7

Source - Meteorological Services

Rainfall data is presented for the regions of Balaclava and Plaisance so as to reflect the amount of rainfall in the Balaclava and Blue Bay marine parks respectively (**Table 3**). The amount of rainfall in the month of February 1998 had departed from normal by 222% and 210% in Balaclava and Blue Bay respectively. This represents more than twice the amount of rainfall for the month of February. Excessive rainfall leads to lowering of salinity in the coastal waters. This is a stress causing factor as

corals thrive in a normal sea salinity of 35 ‰. However, no record of salinity changes were made in these areas and it is difficult to attribute coral bleaching to this factor.

Table 3: Rainfall actual and % departure from normal at BalACLava and Plaisance

	BalACLava						Plaisance					
	1996		1997		1998		1996		1997		1998	
	mm	DFN%	mm	DFN%	mm	DFN%	mm	DFN%	mm	DFN%	mm	DFN%
Jan	187	104	256	143	111	62	162	65	241	96	221	88
Feb	107	57	105	56	420	222	125	51	160	65	517	210
Mar	80	54	94	64	55	37	86	40	112	52	129	59
Apr	115	97	75	63	88	74	146	66	301	136	82	37
May	25	41	101	166	92	151	69	47	105	71	189	128
Jun	34	63	48	89	16	30	46	46	112	111	40	40

DFN % - % Departure from normal

Source : Meteorological Services

Heavy rainfall is accompanied by floods, which in turn increase silt load and sediment concentrations in the coastal waters. Increased turbidity reduces solar light penetration through the water column. This in turn affects photosynthetic rate in the zooxanthellae. Thus decreased carbohydrate fixation by the zooxanthellae affects their symbiotic relationship with the coral polyps. Extended periods of rainfall are usually accompanied by thick cloud cover which eventually become a stress factor by reducing light intensity and hence the photosynthetic activity of the zooxanthellae.

Once the stressful factors are eliminated and normal ambient water conditions prevail, the zooxanthellae gradually recolonize the coral polyps thus reinstating the natural colour of the corals. However, repeated bleaching in succession may lead to death of the coral colonies.

CONCLUSION

Although the maximum temperature off-lagoon was 29.°C, water temperatures in the lagoon could have been higher due to the partly enclosed and shallower conditions, which prevail here, and this could have affected coral health. Rainfall and turbidity might have had the same effect but no records exist of changes in these parameters either. Hence the exact causes of coral bleaching cannot be pinpointed as it could have been due to one or a combination of changes in these parameters. A programme should, therefore, be initiated to measure regularly these data in the sea around Mauritius so as to be able to use them in any future coral bleaching events.

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INVESTIGATION OF THE WATER QUALITY OF BELLE EAU ESTUARY AT ALBION

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ABSTRACT

Agricultural run off and effluents from animal breeding in the area influence water quality of the Belle Eau River. Investigations were carried out to determine the level of contaminants affecting the river and the estuary namely: nitrate-nitrogen ($\text{NO}_3^- \text{N}$), phosphate (PO_4^{3-}), faecal coliform and other physicochemical parameters. This paper examines the variation of the level of contaminants and their impacts on the aquatic environment, if any.

Keywords: estuaries, chemico-physical-properties, water-quality, aquatic environment, contaminants, environment-impact, Mauritius.

INTRODUCTION

The Belle Eau estuary is situated at the southern end of the Albion Public Beach and is fed by the Belle Eau River (**Figure 1**). It is bordered by the Albion Fisheries Research Centre on one side and on the other by the main road and a small residential community. The mouth of the Belle Eau River is about 18 m in width and the widest part of the estuary is about 40 m. The depth throughout the estuary ranges between 0.2 m and 1.2 m. The estuary covers a total length of approximately 250 m. The water quality of the Belle Eau River is being influenced by the inputs derived from land use and human activities in the surrounding region from non-point sources. These land uses include agriculture, animal farming and residential development. Surface water canals, rivulets and streams flow into the river after crossing sugar-cane fields and land under crop cultivation. Surface runoff from these areas carry animal wastes, fertilisers, pesticides and silt into the river and finally to the estuary. The faecal coliform bacteria have been chosen as the indicator in the present investigation to determine the sanitary quality of water of the Belle Eau Estuary. These organisms are associated with the intestinal tract of humans and warm-blooded animals, and are, therefore, useful in detecting faecal contamination in water. It has been shown that pathogenic microorganisms cannot survive for extended periods in natural seawater. The number of bacteria is rapidly reduced in the sea as a result of physical dilution and microbial inactivation, which depend on various environmental factors (Cornax *et al* 1990), (El-Sharkawi *et al* 1989). On the other hand, high levels of nutrients brought into the estuary with the river flow attract many organisms. The productive nature of the estuary provides a suitable habitat and a plentiful food supply for many plants and animals. The diversity of organisms that may survive in an estuary is limited by the fluctuating conditions prevailing within it. This is consequent to the varying temperature, pH, DO (Dissolved Oxygen), COD (Chemical Oxygen Demand) and salinity along the length of the estuary. The objective of this paper is to study the effects of the varying levels of the physicochemical parameters and faecal coliforms on the water quality of the estuary. It also involved identifying the current land uses upstream of the estuary.

MATERIALS AND METHODS

Sample collection

The study was undertaken for a period of about one- year, from August 1997 to July 1998. Water samples were collected at monthly intervals from seven stations (A1 to A7) for bacteriological studies

and from four stations (A4 to A7) for determination of physicochemical parameters. Samples were taken at the surface layer (<50 cm) using 1000 ml sterile glass bottles and stored at below 10°C in an isothermic box during transportation and at 4°C in a refrigerator upon receipt in the laboratory. Samples were processed within 6 hours after collection for bacteriological tests, and on the same day for determination of physicochemical parameters.

Procedures

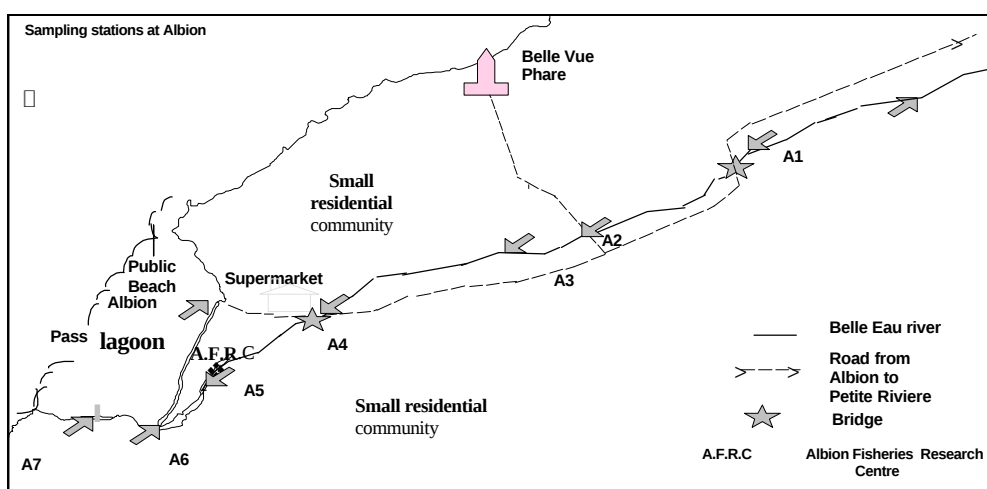
Bacteriological

Water samples were analysed in triplicate for the presence of faecal coliform in the laboratory and quantified using the Membrane Filter method (APHA AWWA WEF 1995). Serial dilutions of the water samples were prepared to obtain the ideal number of 20 to 80 colonies on the 47mm Millipore membrane filters (pore size 0.45 µm). The numbers of colony forming units (CFU) were calculated per 100 ml. For the isolation of faecal coliform, the membrane filters were incubated on cellulose pads saturated with m-FC broth base (DIFCO) (44.5 ± 0.5°C, 24 h). The EC broth (HIMEDIA) (44.5 ± 0.5°C, 24 h) was used to confirm the presence of faecal coliforms.

Physico-chemical

Water samples were collected during low, mid and high tides at stations A4 to A7. Nitrate-nitrogen ($\text{NO}_3^- \text{N}$) and phosphate (PO_4^{3-}) were measured using the HACH DR-2000 direct reading spectrophotometer. Other parameters measured included temperature (recorded in situ with a portable digital thermometer), pH (using a pH meter in the laboratory), salinity (by a conductivity meter), dissolved oxygen (DO) (Winkler's method) and chemical oxygen demand (COD) (alkaline potassium permanganate method).

Figure1. Map of sampling points in the Belle Eau River and Estuary - Albion



Sampling Stations

- A1 - At bridge towards Petite Rivière and just after Belle Vue Experimental station
- A2 - Near poultry farm
- A3 - Near piggery
- A4 - At bridge beside supermarket
- A5 - At bridge near river mouth
- A6 - Mouth of river
- A7 - Slipway facing river mouth

RESULTS

Fæcal Coliform Densities

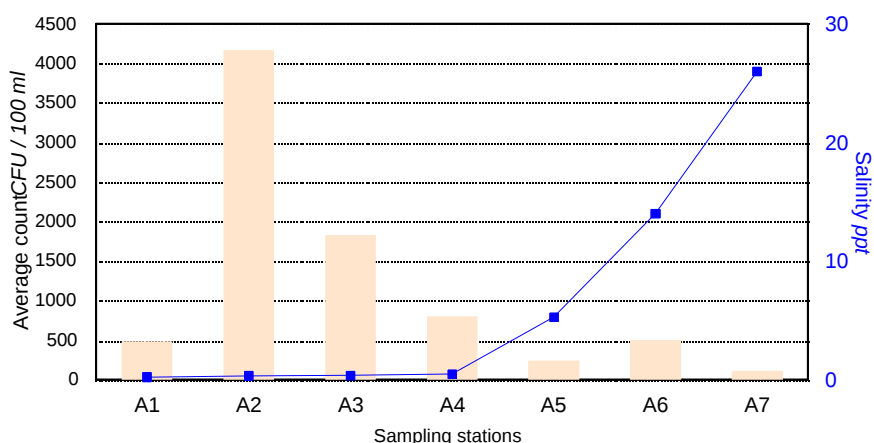
Table 1 shows the mean fæcal coliform densities along the Belle Eau Estuary and part of Belle Eau River. Fæcal coliform counts ranged from 4 (A7) to 6 670 (A2) CFU / 100ml. **Figure 2** clearly indicates that an increase in salinity produced a sharp decrease in the density of fæcal coliforms. However, station A6 shows a sudden rise of fæcal coliform densities as it received discharge from the adjacent residential area, irrigation waters and agricultural land. The pH levels recorded during the investigation ranged from 7.2 to 8.4 with the highest values at A2 and A3 in the freshwater part of the river and A7 in the lagoon. The temperature varied by 2°C between the station found upstream river Belle Eau (A1) and the one found in the lagoon (A7).

Table 1 Measured Parameters along the Belle Eau Estuary and part of Belle Eau River

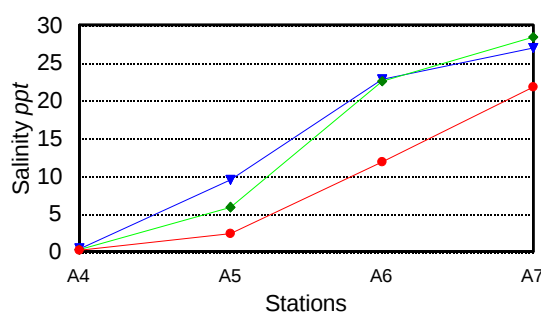
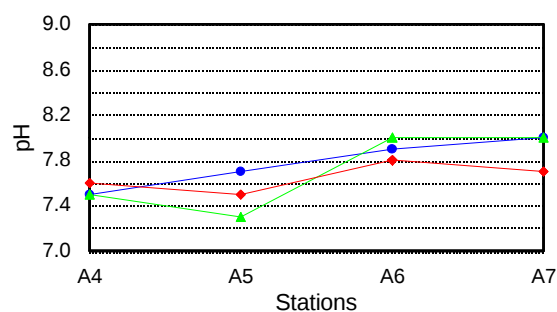
Station	Fæcal coliform CFU* / 100ml	Salinity ppt	Temp °C	pH
A1	480	0.20	25	7.7
A2	4 170	0.30	25	8.0
A3	1 830	0.34	25	8.1
A4	800	0.45	26	7.8
A5	240	5.25	26	7.6
A6	500	14.00	27	7.7
A7	110	26.00	27	8.1

* CFU Colony forming units

Figure 2 Fæcal coliform density in the Belle Eau River CFU / 100ml
Physicochemical parameters (A4 - A5)

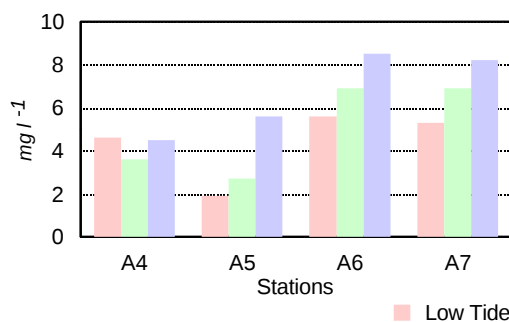
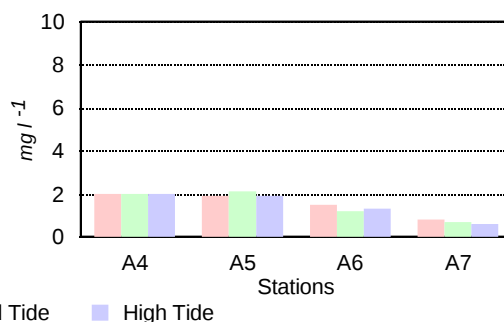


Figures 3 to 8 show the average values of physicochemical parameters collected at three tides. At high tide salinity ranged from about 0 ppt at station A4 to 35 ppt at station A7 in the lagoon (**Figure 3**).

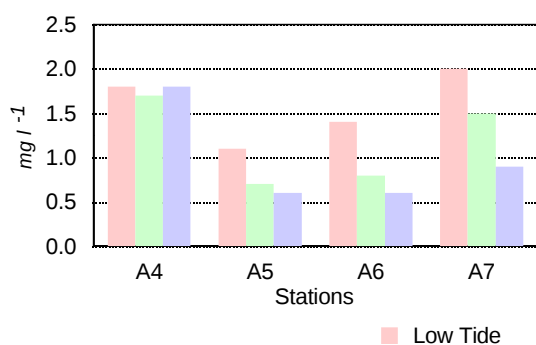
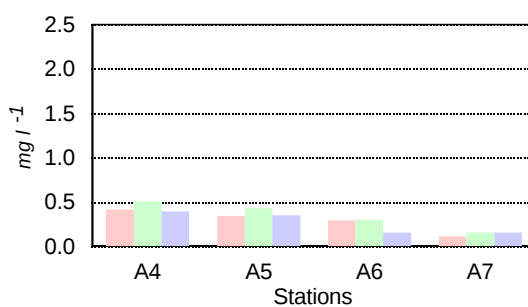
Figure 3 Salinity**Figure 4** pH

The pH recorded ranged between 6.7 and 8.4 with the lowest value at station A5. The pH values were higher at stations A6 and A7 (**Figure 4**).

The lowest dissolved oxygen value was recorded at low tide at station A5 (0.3 mg l^{-1}). DO values ranged from 0.3 to 9.6 mg l^{-1} increasing gradually downstream towards the sea (**Figure 5**).

Figure 5 Dissolved oxygen mg l^{-1} **Figure 6** Chemical oxygen demand mg l^{-1} 

COD values ranged between 0.1 to 3.6 mg l^{-1} with higher levels at stations A4 and A5 and lowest at A7. Nitrate values recorded were from <0.1 to 3.8 mg l^{-1} (**Figure 7**).

Figure 7 Nitrate mg l^{-1} **Figure 8** Phosphate mg l^{-1} 

Phosphate values were highest at A4 with a value of 0.71 mg l^{-1} while at A7 station found in the lagoon the values were less than 0.01 mg l^{-1} (**Figure 8**).

Species composition of the Estuary

The estuary consists of fish species able to tolerate variable salinity conditions and exhibits a rich biodiversity. This is apparent from **Table 3**, which lists the species recorded during the seining operation effected in June 1998 in the part of the estuary, which indicated salinity of 5 ppt to 18 ppt (A5 to A7).

Table 3. Some species recorded in the Belle Eau estuary

Serial No	Species	Vernacular Name	
		Mauritius	Standard
1	<i>Mugil seheli</i>	Mulet sec	Blue-tailed mullet
2	<i>Mugil cephalus</i>	Mulet voilé	Mangrove mullet
3	<i>Mugil sp.(juvenile)</i>	Milton	Juvenile mullet
4	<i>Polydactylus plebejus</i>	Barbet	Bastard mullet
5	<i>Caranx melampygus (juvenile)</i>	Carangue sardine	Blue fin trevally
6	<i>Caranx ignobilis (juvenile)</i>	Carangue piece noire	Giant trevally
7	<i>Trachinotus bailloni</i>	Carangue ronde	Baillon's dart
8	<i>Sparus sarba</i>	Gueule pavé	Silver sea-bream
9	<i>Leiognathus equulus</i>	Sap-Sap	Common pony fish
10	<i>Gerres oyena</i>	Breton	Silver-biddy
11	<i>Monodactylus argenteus</i>	Lune argentée	Silvery-moon
12	<i>Sphyræna jello</i>	Tazar	Barracuda
13	<i>Sphyræna barracuda</i>	Tazar lichien	Barracuda
14	<i>Parupeneus bifasciatus</i>	Rouget	Goat-fish
15	<i>Parupeneus multifasciatus</i>	Rouget	Goat fish
16	<i>Leptoscarus vaigiensis</i>	Marbled parrot fish	Marbled Parrot fish
17	<i>Elops machnata</i>	Ladyfish	Ladyfish/springer
18	<i>Lutjanus fulviflamma</i>	Giblot	Black-spot sea-perch
19	<i>Arothon sp.</i>	Bouletangue	Puffer fish
20	<i>Corythoichthys sp.</i>	Pipefish	Pipefish
21	<i>Hyporhamphus sp.</i>	Aiguille	Needle fish
22	<i>Glossogobius spp.</i>	Cabot	Goby
23	<i>Ophiocara porocephala</i>	Cabot des Seychelles	Flathead sleeper
24	<i>Siganus sutor</i>	Cordonnier	Rabbit fish
25	<i>Clupea spp.</i>	Petite sardine	Sardine
26	<i>Oreochromis spp.</i>	Tilapia	Tilapia
27	<i>Scylla oceanica</i>	Crabe carlet	Mangrove crab
28	<i>Nerita sp.</i>	Bigorno	Nerite
29	<i>Septifer sp.</i>	Moule	Mussel
30	<i>Hormomya sp.</i>	Moule	Mussel
31	<i>Palaemon sp.</i>	Crevette d'eau douce	Fresh water shrimp

DISCUSSION

A general analysis of the samples showed that faecal coliform bacteria were most abundant upstream river Belle Eau, namely at stations near the piggery (A3), the poultry farm (A2), and where there were inputs of agricultural runoff (A6) which had passed through cattle grazing and rearing grounds higher up in the basin. It has also been shown that pasture runoff in rural watersheds contribute significant faecal coliform amounts to receiving waters (Faust and Goff 1977, 1978).

Faecal coliform counts decreased in the Belle Eau Estuary and were minimum near the slipway, a station facing the river mouth and located in the lagoon. The levels of faecal coliform along the river were above the normal limits (200CFU / 100ml) for swimming at Stations A1 to A6, but were within the normal limits for fishing (1000 CFU / 100ml) at all stations except A2 and A3. However, with the present record of coliform density in the estuary, there was no evidence of malformation, fin erosion and skin lesions of fish caught during seining.

Normally when faecal coliform bacteria reach an aquatic system there are several environmental factors, which affect its die-off rates. These factors include high salinity, turbidity, solar radiation, predation, pH and temperature (EPA 1993), (NCDEHNR 1994). Faecal coliforms, which settle out of the water column, encounter a favourable non-starvation environment in the estuarine sediment, where

they can survive and reproduce for several months (Davies et al 1995). These bacteria can be circulated back up into the water column in storms or other turbulence generating processes, leading to increased waterborne coliform levels (Paerl H Personal communication). This cycle may greatly prolong the influence of a contamination event on faecal coliform levels in the estuary.

Salinity of water, which has a significant influence on the species composition of the resident biota, fluctuated within the estuary with the ebb and flow of tides and with changes in fresh water runoff. The species recorded in the estuary were mostly euryhaline organisms, able to withstand a wide range of salinity. Station A4 showed no salinity variation with the tides but downstream at A5, A6 and A7 salinity varied. The landward and seaward limits of an estuarine system as defined by Cowardin et al 1979 "...extend upstream and landward to the place where ocean derived salts measure less than 0.5 parts per thousand during the period of average annual low flow. The seaward limit is an imaginary line closing the mouth of the river or bay..." During the investigation and based on the above definition, stations A1 to A4 were considered as the freshwater part of the river, while stations A5 to A7 were considered as the estuarine portion of the river. The part between A4 and A5 could be referred to as the head of the estuary.

Phosphorus and nitrogen, primarily in the oxidised forms of phosphate (PO_4^{3-}) and nitrate (NO_3^- N) respectively entered the estuary from different sources, both natural and from human activities. The natural sources include the decomposition of organic matter and the runoff of undomesticated animal wastes following precipitation. Manmade sources include agricultural runoff, animal wastes, septic tank leakage and domestic wastes. Inputs from these sources caused enrichment of the Belle Eau estuary. Nitrate concentrations were within the normal range and generally low at stations under the influence of seawater except for station A7 where input of fresh water due probably to the nitrogen-based fertilisers used in the basin affected the results. On the other hand, phosphate concentrations decreased towards the sea and were within the normal range.

Dissolved oxygen is a fundamental requirement for all life. Many countries set water quality standards at a threshold concentration of 5.0 - 6.5 mg l^{-1} . A concentration of approximately 2 mg l^{-1} is thought to be stressful to most estuarine organisms. These low levels most often occur in bottom waters and may affect the organisms that live in the sediments. Oxygen concentrations were at their lowest at low tide. The rising tide raised the oxygen concentration due to the influx of seawater rich in oxygen. Low levels of oxygen recorded at A5 during low tide might be due to the low river flow and low water circulation at this station.

Water temperature ranged from about 22 °C in winter to 31 °C in summer. The pH values in the Belle Eau Estuary were within the recommended range (6.5 to 9.0) at all the stations but were slightly higher where there were inputs of animal waste (A2 and A3) upstream.

Average COD values of around 2.0 mg l^{-1} at stations farthest inland (under the influence of freshwater inputs) gradually decreased towards the sea to attain an average value of less than 1.0 mg l^{-1} at station A7. The relatively higher values of COD might be attributed to the presence of organic matter in the fresh water draining the region. The lower values at stations near the sea might be a result of dilution by input of seawater from the lagoon.

The Belle Eau estuary is characterised by the sediment load, suspended particles and detritus it carries in its water column during rainfall and the flow and ebb of tides. The water clarity is therefore, reduced considerably and inhibits phytoplankton production (Ragotzkie, 1959).

CONCLUSION

The present investigation demonstrates that the indicator bacteria used (faecal coliform) and the other physicochemical parameters do not affect the fish community in general. Further studies are required to assess the biological and physicochemical aspects of the estuarine water. However, it can be concluded that the use of the river water may pose a potential health hazard in the river but is safe for swimming in the lagoon, near the slipway.

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AN ASSESSMENT OF LETHRINUS RUBRIOPERCULATUS ON SOUDAN BANK

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ABSTRACT

Lethrinus rubrioperculatus represents 49.1% of the catch on the Soudan bank. Studies on the biology and this species started in 1995, with samples obtained from the commercial fishery boats operating on the Soudan bank and from the research vessels of the Fisheries Division. Preliminary results from length frequency data analysis, (LFDA package) indicates a growth rate of 0.18 per year and $L_{\infty} = 57.1$ cms. Natural mortality (M) was estimated at 0.42 per year and fishing mortality (F) was 0.56 per year. The length at first capture (L_{c50}) was estimated at 28 cms. Furthermore, maturity studies tend to indicate two distinct period of spawning: February, March and October. Preliminary estimation of Maximum Sustainable Yield (MSY) on the Soudan bank gave a yield of 236 tons. Analysis suggests that the optimal fishing effort, excluding economic considerations, is approximately 10 boats, (less than 20 metres).

Keywords : Soudan bank, *Lethrinus rubrioperculatus*, fishery-management, fishery-biology, Mauritius.

INTRODUCTION

The Soudan Bank (lat.18°28' S and long. 58°49' E), located at 120 nautical miles from Port Louis, Mauritius, has been fished over the last few years by a small fleet of 3 to 4 fishing boats. Preliminary survey and test fishing carried out on this bank indicate a good potential for *Lethrinus* spp, with *L.rubrioperculatus* predominating. Further investigation is necessary before any final conclusion can be made. A survey was conducted since 1995, to assess the state of the stock and determine species composition on this bank. *Lethrinus rubrioperculatus* represents 24.4% and 35.2 % of the total catch by weight (research vessels and commercial fishing data), followed by *Aprion virescens*, *L.Mahsena* and *L. elongatus*. Out of the 2059 fishes sampled on the Soudan bank, *L.rubrioperculatus* by itself represents 49.1%, nearly half of the catch by number, (research vessels data).

This paper provides a preliminary assessment of the stock of *Lethrinus rubrioperculatus* based on the data collected by the research vessels "Coryphaena" and "Sphyrna II". The paper also provides an insight on the gonad stages and spawning period of this species on the Soudan bank.

METHODS

Catch, effort, weight and fork length data were recorded from the research vessels. Furthermore, total catch data from private fishing boats were also collected at landings for statistical and analytical purposes.

Both research vessels used four lines each, hydraulic deep sea reels for "Coryphaena" and hand lines for "Sphyrna II". Each lines were fitted with five hooks for fishing and fishing time were limited to one day, (approximately nine fishing hours). Length frequency data were analysed to estimate L_{∞} and the growth rate K , using the Length Frequency Data Analysis, (Holden and Bravington 1992) computer programme. L_{∞} and K are the growth parameters of the Von Bertalanffy growth equation,

$$L_t = L_{\infty} (1 - \exp(-Kt))$$

Length frequency data were then re-analysed using the computer programme "LFANAL" (King1990). Mortality rates were estimated by means of a length - converted catch curve, and Length - weight relationship were determined by fitting power curves through length and weight data.

Depth of fishing

Fishing was carried out mainly at depth of 50 - 60 metres for lethrinid species. Trials were also made at depth of 200 metres and above at the edge of the Soudan bank for deep-water snappers. Species caught were mainly *Elelis coruscans*, *Etelis carbunculus*, *Pristipomoides auricilla* etc. The percentage catch of these species represents less than 20 % of the total catch on the Soudan bank.

RESULTS

Table 1 gives the species composition on Soudan bank.

Table 1 Species composition and percentage.

Species	Records	%.	Research Vessel		Commercial Boats	
			Weight			
			Kg	%	Kg	%
<i>L.rubrioperculatus</i>	1 012	49	622	24	10 275	35
<i>L.mahsena</i>	103	5	173	7	3 131	11
<i>L. elongatus</i>	196	10	295	12	413	2
<i>P.auricilla</i>	193	9	155	6	-	-
<i>A.virescens</i>	125	6	477	19	2 703	9
<i>E.coruscans</i>	31	2	105	4	3 019	12
<i>E.carbunculus</i>	40	2	146	6		
Others	359	17	575	23	9 028	31
Total	2 059	100	2 548	100	28 569	100

Others includes *P.filamentosus*, *G.griseus*, *V.louti*, *L.bohar*, *S.dumerili*, *Thunnus spp*, *Sharks* etc.

The catch per fishermanday (CPFD) amounted to 67.8 Kg for the reaseach vessel. This compares favourably to semi - industrial fishing boats where CPFD was estimated at 51.6 kg . **Table 2.** gives the catch recorded for commercial fishing boats.

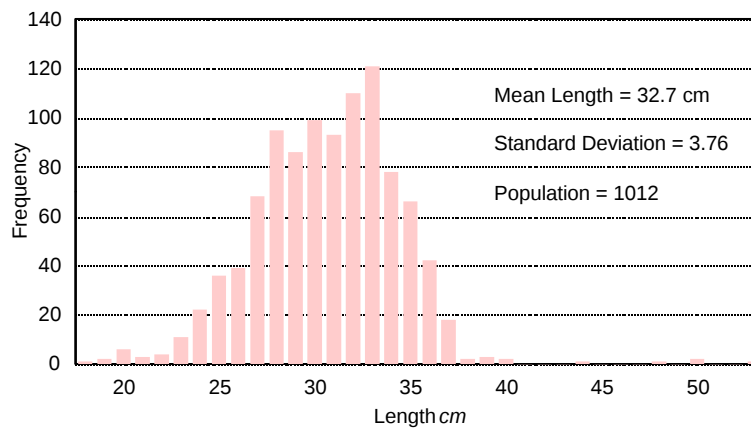
Table 2. Catch recorded Kg

Year	Vessels		
	Commercial	Research	Réunion*
1995	31 650	2 548	25 000
1996	28 638	0	0
1997	29 169	0	0

* The catches from Réunion boats are estimates only.

On Soudan bank, *Lethrinus rubrioperculatus* represents nearly half the catch obtained. The weight varied from 0.2 kg to 1.1 kg and length recorded varied from 20 cms to 55 cms with a mean length of 32.7 cms. **Figure 1** gives the length frequency obtained. .

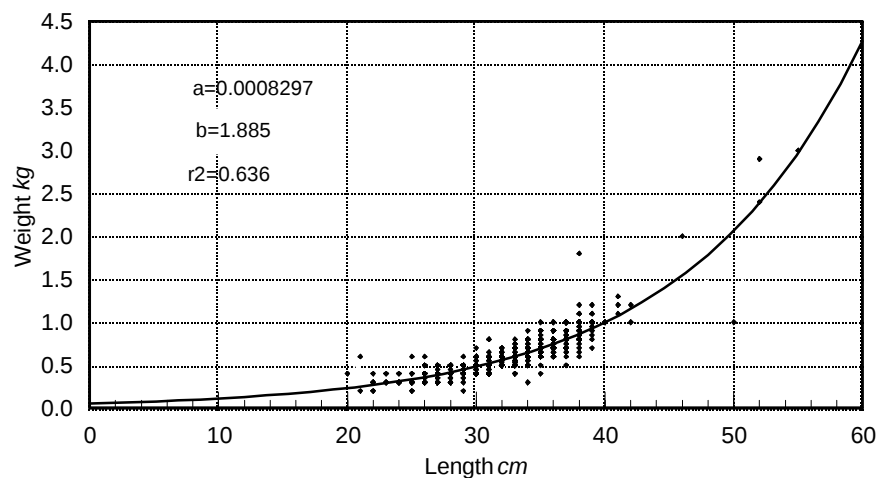
Figure 1 Length frequency of *L.rubrioperculatus*



Length - weight relationship

A length - weight relationship of the form $W = aL^b$ was fitted, where W is the weight in kilograms and L is the length in cms and a and b are constants. Figure 2 gives a graphic representation of this relationship.

Figure 2 Relationship of Length to Weight for *L.rubrioperculatus*.



Growth

The growth parameters L_{∞} and K, of the Von Bertalanffy growth equation were calculated using the equation

$$L_t = L_{\infty} (1 - \exp(-Kt))$$

The asymptotic length, L_{∞} was estimated at 57.1 cms and the growth rate K was found to be 0.18 per year. Corresponding ages for length and weight for *L.rubrioperculatus* are given below.

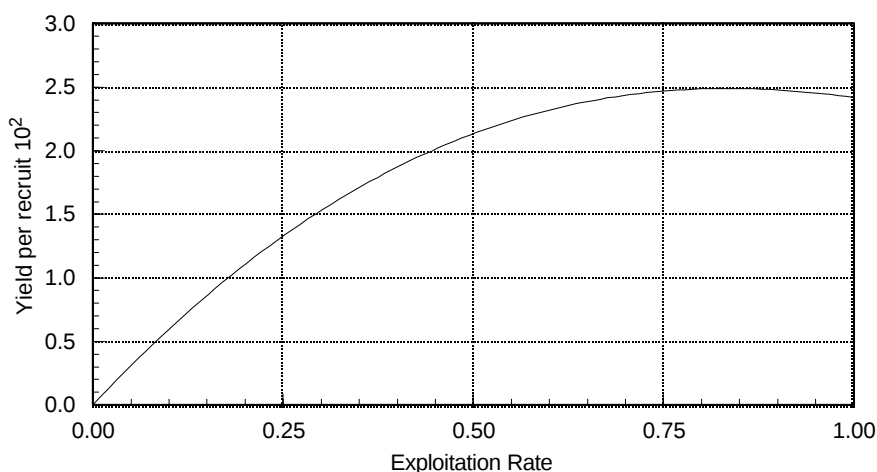
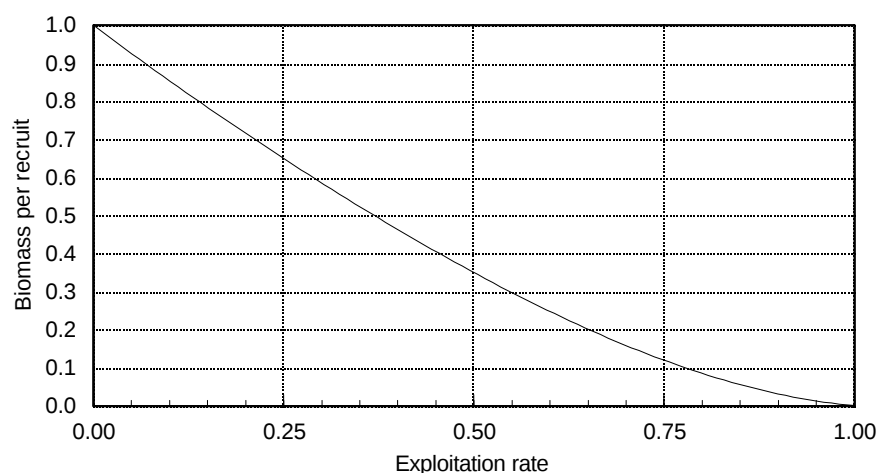
Table 3 Corresponding ages for length and weight.

Age Yr	0	1	3	5	7	9	11	12	13	14
Length cm	2.0	11.1	25.0	34.7	41.5	46.2	49.5	50.8	51.8	52.7
Weight Kg	0	0.08	0.36	0.66	0.93	1.14	1.30	1.36	1.41	1.46

Results obtained compares favourably with those of Bautil and Samboo (1987). They found L_{∞} at 61.7 cms and K at 0.100 for *Lethrinus mahsena* on Nazareth Bank. Bertrand et al (1986) reported L_{∞} at 60 cms and K at 0.1 for stock of *L. mahsena* found on the Saya de Malha bank. Mees (1996) found L_{∞} at 58.9 and K at 0.32 for *Lethrinus mahsena* at Chagos and Pitt banks. However, studies on *L. rubrioperculatus* in the Marianas gave the growth parameter K at 0.22 and L_{∞} at 30.8 cms (Ralston and Williams 1988).

Mortality

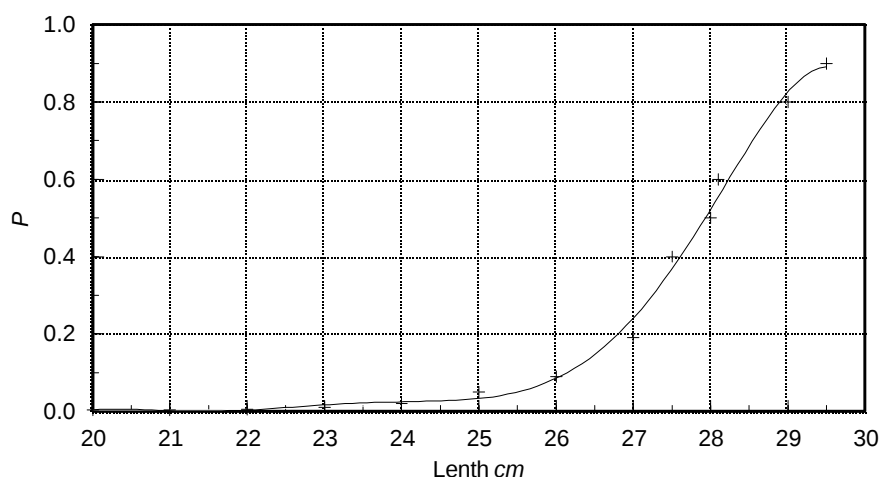
Length - converted catch curves were used to estimate the mortality rate of the species under study. The total mortality, Z was found to be 0.98 with a coefficient of determination of 0.87. Natural mortality M was estimated at 0.42 using Pauly's M equation and fishing mortality F at 0.56 (Z - M). The fact that the Soudan bank has been fished for a number of years could account for the high fishing mortality obtained. Furthermore, exploitation rate was estimated at 36% of the biomass, (Figure 3 & 4).

Figure 3 Exploitation Rate : Yield per recruit

Figure 4 Exploitation Rate : Biomass per recruit


Length and age at first capture

Hook size No.23, (Maruti B.K.N, Japan) were used during test fishing on Soudan bank. The distance between point and shank was 18 mm. The minimum length of fish captured was 20 cms and this corresponds to an age of 2.5 years. The maximum length of *L.rubrioperculatus* captured was 55 cms corresponding to 19 years. The length at first capture, L_{c50} was estimated at 28 cms.

Figure 5 Length at first capture



Maximum sustainable yield

Soudan bank occupies a surface area of 615 km². Catch rate has been estimated at 67.8 Kg per fisherman day for the research vessels and at 51.8 kg per fisherman day for commercial fishing boats. In the absence of a depletion experiment, the bait attraction method was used to calculate the biomass. A preliminary estimation of the yield was made using Gulland's (1983) formula,

$$Y = 0.5 * B * M$$

Where Y is the yield, B represents the biomass (1127 tonnes) and M the natural mortality (0.42). This equation is likely to overestimate yield (Beddington and Cook 1983) but it provides an indication for management purposes.

Thus, MSY stands at 236 tonnes. A potential yield of 380 Kg / Km² as compared to 200 Kg / Km² around St.Brandon area, Nazareth and Saya de Malha bank, (Mees 1996).

Maturity stages of gonads

Studies on the gonads of *L.rubrioperculatus* were carried out to determine the spawning season and the changes in gonad stages with time. Gonads were classified from stage 1 to 7, with stage 1 barely visible and immature and stage 7 at resting stage. (Fontana 1969). Results are shown graphically.

Figure 6 Gonad stages with time.

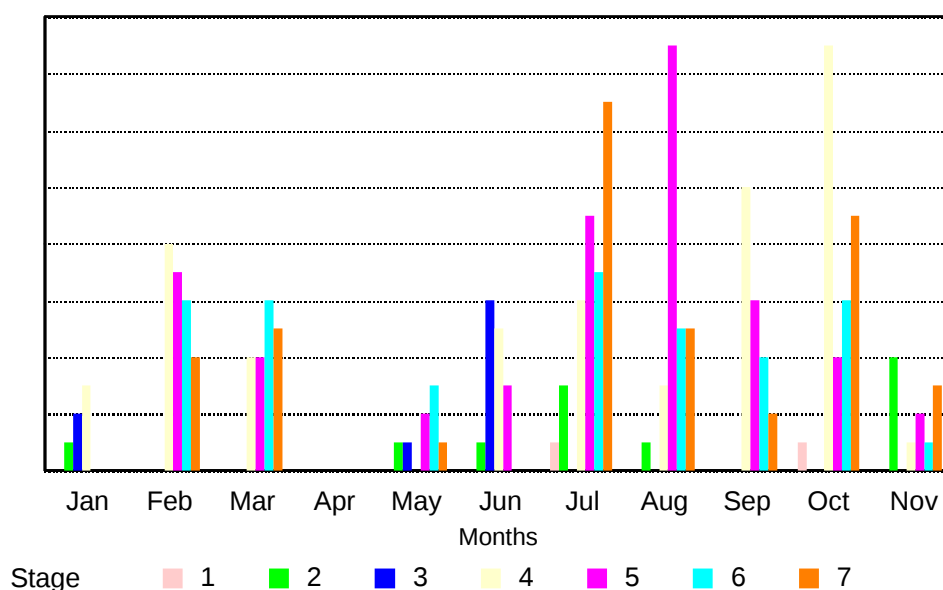


Figure 6 shows that stage 5 peaks out in July/August with a small peak in February. At stage 4 the fish is fully mature and ready for spawning, with spawning at stage 5. No data was available for the months of April and December. Results clearly indicate two spawning periods for *Lethrinus rubrioperculatus*, one in February and a more pronounced one in July/August. It is worthy to note that the peak spawning period falls at the end of the winter season, i.e the time when most of the fishing boats are berthed in port and no fishing takes place due to rough sea conditions, hence an auto regulatory measure.

Advanced gonad stages have been recorded from October to February with a peak spawning period in December in New Caledonia, (Carpenter 1996). Nevertheless, careful monitoring and good management measures should be taken to prevent depletion of this resource. In 1995, a licensing system was introduced to restrict entry for fishing on Soudan bank. Presently, only 5 commercial boats are licensed to operate on this bank.

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PROSPECTS AND POTENTIAL OF GROWING VEGETABLE SOYBEAN (*GLYCINE MAX* (L) MERRILL) IN MAURITIUS

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ABSTRACT

Field trials with vegetable soybean cultivars were carried out over a three-year period in the humid, super-humid and sub-humid zones at the Central, Curepipe and Richelieu Experiment Stations respectively. These were supplemented by on-farm testing in the regions of Dubreuil, Vacoas, La Marie, Trianon, St Martin, Flacq and Plaisance. Out of the 10 soybean cultivars introduced from the Asian Vegetable Research and Development Centre (AVRDC) in 1995, 2 cultivars namely AGS 332 and 333 were initially screened out because of low yields and long crop cycles. Eight cultivars were retained: AGS 292, 329, 330, 336, 337, 338, 339 and 340. These can be grown all the year round through out the island with yield of fresh pods ranging from 11 to 15 t ha⁻¹ over a crop cycle of 85 to 100 days. Higher yields have been obtained in summer. Soybean can thrive under marginal soil conditions. It can tolerate a high water regime and low soil pH as reflected by its performance in the upland regions of the tea diversification areas. Cultivars AGS 337, 292 and 339 were the best performers in terms of yield and pod quality.

Keywords : soybean, *Glycine max*, variety trials, Mauritius

Introduction

The soybean, *Glycine max* (L) Merrill is a herbaceous annual legume with a bushy, erect and rather leafy plant structure. It originated from China around 1100 to 1700 BC but was introduced into Europe only in the 17th century (Sinclair and Backman 1989). It has acquired a world-wide importance as a primary source of vegetable oil and protein and is traditionally grown to that end.

During the 1980s, the Asian Vegetable Research and Development Centre (AVRDC) re-directed its research activities towards the breeding of new soybean cultivars that are better adapted for use as a vegetable. Several vegetable soybean cultivars have been developed which are widely grown in many South East Asian countries and even in India because of high yields, adaptability to marginal soils and high nutritive value. Vegetable soybean is harvested when the pod is still green with mature green seeds filling 80-90 % of the pod width. It differs from grain soybean in that it has larger pods and seeds with a slightly sweet taste. Nutritionally, it contains a higher percentage of protein than any other pulse crop with 40 % of protein, 20 % fat (without cholesterol), 33 % carbohydrate, 6 % crude fibre and 5 % ash (on a dry weight basis) (Shanmugasundaram 1996). It is a rich source of calcium, iron, potassium, ascorbic acid and vitamin E. The fatty acids linolic and linoleic acids together with the phospholipid, lecithin contained in soybean prevent the deposit of cholesterol on the walls of blood vessels and exercise a beneficial effect on the control of hypertension (Horii 1997).

RESEARCH OBJECTIVES AND STRATEGY

The main purpose of testing vegetable soybean in Mauritius is to broaden the range of vegetables available on the local market. In 1995, ten vegetable soybean cultivars namely AGS 292, 329, 330, 332, 333, 336, 337, 338, 339 and 340 were introduced from AVRDC in Taiwan. A research programme was initiated over a three-year period. In the initial phase, preliminary trials were conducted to have a basic understanding of the crop growth habit and pattern. Emphasis was laid on crop characterisation in respect to attributes such as days to 50 % flowering, plant height, length of pod, number of pods per plant, percentage of 3-seeded pods, shelling out percentage and crop cycle. The second phase was focused on the testing of the adaptability of various vegetable soybean cultivars to different agro-climatic conditions both on-station and on-farm. Special consideration was given to key

factors such as seasonality, soil types, soil pH fluctuations, climatic zones, and water regime under rainfed and irrigated conditions.

MATERIALS AND METHODS

All the field trials carried out under this project were set up in a randomised complete block design with 3 replicates. A plot size of 7.5 m² was used with 5 rows of plants 50 cm apart. Seeds were sown at 5 cm within the 3 m rows. Basal fertilisers at the rate of 30 kg N ha⁻¹, 100 kg P₂ O₅ ha⁻¹ and 100 kg K₂O ha⁻¹ in the form of sulphate of ammonia, triple superphosphate and muriate of potash respectively were applied at planting in supplement to farm yard manure at the rate of 20 t ha⁻¹. All the plots were weeded manually once during the first month of crop establishment. Phytosanitary control was restricted to one application of abamectin (Vertimec 1.8 EC at 300 ml ha⁻¹) against leaf miners three weeks after sowing. Other cultural practices were followed according to the AVRDC standard recommendations (Shanmugasundaram 1979).

RESULTS AND DISCUSSION

Crop characterisation

This study was conducted in joint collaboration with the AVRDC. Observations and data were recorded from two vegetable soybean cultivar trials performed at the Central Experiment Station at Réduit in summer (November 95) and in winter (August 96). Following the established AVRDC experiment protocol, several plant parameters were characterised; however, only 7 characteristics relevant to this paper are presented. These are the number of days to 50 % flowering, plant height, length of pod, number of pods per plant, percentage of 3-seeded pods, shelling out percentage and the crop cycle (**Tables 1** and **2**).

Table 1 Characteristics of vegetable soybean cultivars under test at Réduit in November 95.

Variety	Days to 50% flowering	Mean Crop Cycle days	Mean height of plant cm	Mean no of pods / plant	Mean Length of pod cm	3-seeded pods %	Shelling out %	Mean yield of fresh pods t ha ⁻¹
AGS 292	29	86	42 ^{ef}	27	6.1	38	53	14.7
AGS 329	28	84	51 ^{cde}	32	6.2	49	55	13.0
AGS 330	33	86	53 ^{cd}	34	5.3	16	53	14.5
AGS 332	39	103	81 ^b	29	5.3	8	53	7.5
AGS 333	33	96	56 ^{cd}	33	5.6	12	62	11.6
AGS 336	33	87	93 ^a	34	5.6	26	57	14.3
AGS 337	32	86	60 ^c	45	5.7	34	57	15.6
AGS 338	31	83	60 ^c	24	6.2	34	52	14.3
AGS 339	28	85	47 ^{de}	24	5.9	32	54	13.4
AGS 340	26	81	34 ^f	39	5.6	12	60	13.9
SE ±			2.8	4.8				1.4

Mean followed by same letters are not significantly different at P = 0.05.

Table 2 Characteristics of vegetable soybean cultivars under test at Réduit in August 96.

Variety	50 % flowering days	Crop cycle days	Mean plant height cm	mean no of pods / plant	Mean yield of fresh pods t ha ⁻¹
AGS 292	33	96	28 ^{de}	18	9.2
AGS 329	32	92	32 ^{cd}	18	12.6
AGS 330	37	102	34 ^{cd}	12	10.2
AGS 336	37	108	61 ^a	18	13.1
AGS 337	37	107	50 ^b	24	13.7
AGS 338	35	100	36 ^c	17	12.1
AGS 339	32	92	30 ^{de}	16	10.2
AGS 340	30	88	25 ^e	16	10.3
S.E ±			1.9	2.3	0.9

Means followed by same letters are not significantly different at $P = 0.05$

A brief comment on each characteristic was attempted and may be presented as follows:

Days to 50 % flowering

The vegetable soybean cultivars under test flowered 4 to 5 days earlier during the Summer - November trial (mean max. temperatures 27.8° C to 29.8° C and mean min. temperatures 15.6° C to 19.1° C) compared to the winter- August trial (mean max. temperatures 24.0° C to 24.9 ° C and mean min temperatures 14.3 to 16.6° C). AVRDC conducted trial has shown that the earliest flowering period is normally achieved at 30°C (Inouye and Shanmugasundaram 1983)

Plant height

Significant differences in plant height varying from 25 cm to 92 cm were recorded for the cultivars AGS 340 and AGS 336 respectively. The latter has shown a strong tendency to lodge.

Number of pods per plant.

The average number of pods per plant varied from 16 to 45 depending on the cultivars and the planting season. The highest record was achieved by cultivar AGS 337 with twenty-three pods per plant in winter and forty-five pods per plant in summer.

Pod characteristics

The entries AGS 292, 329, 336, 337, 338 and 339 produce longer pods ranging from 5.2 to 6.6 in length and a higher percentage of 3-seeded ones ranging from 26 to 49 % compared to the cultivars AGS 330, 332, 333 and 340 with mean pod length varying from 4.8 to 5.9 cm and the percentage of 3-seeded ones ranging from 8 to 16. The shelling-out percentage for the various cultivars based on a 500 g pod samples varied from 52 to 62 % with the highest figure for cultivar AGS 333.

Crop Cycle

Longer crop cycles varying from 88 to 108 days were recorded in the winter trial as compared to 80 to 89 days in the summer trial. The two cultivars AGS 332 and 333 were particularly late and because of their low yields of fresh pods of the order of 7.5 t ha⁻¹ and 11.6 t ha⁻¹ respectively; they were screened out.

Agronomic performance

The agronomic performance of vegetable soybean was investigated in respect to seasonal behaviour, variations in climatic zones, soil types and tolerance to varying soil pH and water regime under irrigated and non-irrigated rainfed conditions.

Seasonal behaviour

Trials conducted at the Central Experiment Station in Réduit in November 1995 and August 1996 as illustrated in Tables 1 and 2 show that higher yields of fresh pods of the order of 13 to 15.6 t ha⁻¹ were obtained in summer compared to 9.2 to 13.7 t ha⁻¹ in winter for the soybean cultivars under test. This seasonal adaptation in terms of an increase in the yield of fresh pods of the order of 3 to 4 t ha⁻¹ and a reduction in the crop cycle of the order of 8 to 10 days were confirmed in further field trials which were conducted in the summer months of January 97, February 97, September 97 and February 98 at Vacoas, Dubreuil, Curepipe and Saint Martin respectively in comparison with the winter months of April 96, May 96, March 97 and March 98 at Trianon, Plaisance, Curepipe and La Marie respectively.

In general, the basic trend noted for any specific cultivar is that plants raised in summer had a shorter crop cycle; grew taller, flowered earlier and had a higher number of pods per plant resulting in better yields of fresh pods than winter crops.

Crop response under different climatic zones

The performance of vegetable soybean in different agro-climatic zones in the humid, super-humid and sub-humid zones at the Central, Curepipe and Richelieu Experiment Stations respectively was evaluated under 3 sets of trials performed in 1997 and 1998. The results of only 2 sets of trial are presented to illustrate the underlying trends observed. In the first set of trials carried out in March 1997, 8 vegetable soybean cultivars were tested at the Curepipe and Richelieu Experiment Station. Assessment was based on the number of days to harvest, number of days to maturity (crop cycle) and the yield of fresh pods.

The results are tabulated in **Table 3** and **Figure 1**.

Table 3 Performance of 8 vegetable soybean cultivars at Richelieu and Curepipe in March 1997.

Variety	First harvest		Crop cycle		Mean yield of fresh pods	
	days		days		t ha ⁻¹	
	Richelieu	Curepipe	Richelieu	Curepipe	Richelieu	Curepipe
AGS 292	*	75	*	85	*	12.6 ^{ab}
AGS 329	63	75	77	84	14.6 ^{bcd}	10.9 ^b
AGS 330	70	80	83	95	12.6 ^d	7.2 ^c
AGS 336	70	80	83	95	18.2 ^b	13.3 ^a
AGS 337	70	80	83	95	23.5 ^a	14.0 ^a
AGS 338	*	80	*	93	*	12.4 ^{ab}
AGS 339	63	75	77	84	16.0 ^{bc}	13.0 ^{ab}
AGS 340	63	75	75	82	14.3 ^{cd}	10.7 ^b
S.E ±					1.1	0.7

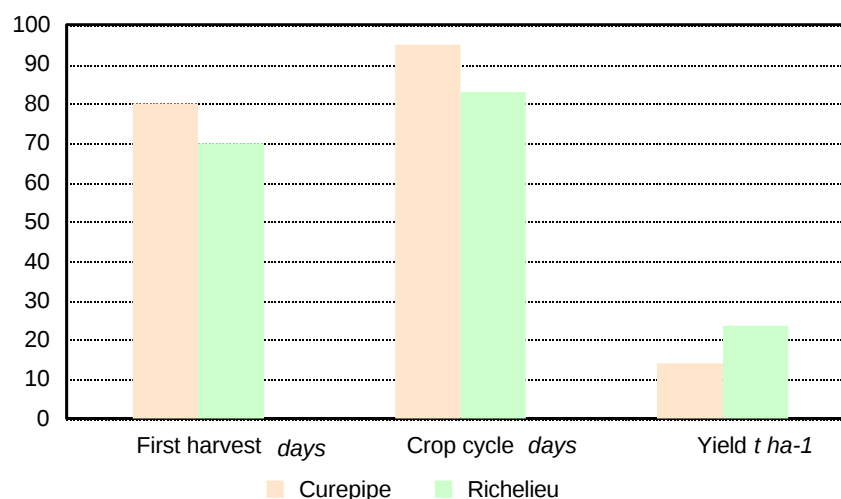
* Seeds not available

Means followed by same letters are not significantly different at $P = 0.05$

The maturity period and the crop cycle was reduced by 7 to 12 days and a yield increase of 3 to 9 t ha⁻¹ of fresh pods was recorded for the soybean cultivars under trial at the Richelieu Experiment Station in comparison to the Curepipe Experiment Station, Table 3.

These observations are believed to be due to better soil fertility coupled with the higher temperatures (mean minimum, temperatures 19.2 °C to 21°C and mean maximum, temperatures 26.9 °C to 30.4 °C) prevailing at Richelieu compared to the lower temperatures (mean minimum temperatures 15 °C to 19.6 °C and mean maximum, temperatures 20 °C to 25 °C) occurring at Curepipe during the crop cycle. These variations are further illustrated in Figure 1.

Figure 1 Performance of cultivar AGS 337 at Richelieu and Curepipe



In the second set of trial conducted in February 1998, only the 5 most promising cultivars namely AGS 292, 329, 337, 338 and 339 were tested on all the three stations.

The results are tabulated in **Table 4**. A gradual reduction in the yield of fresh pods was recorded for all the 5 promising cultivars under test with the highest yield at the Richelieu Experiment Station followed by a medium yield in Réduit and the lowest yield at the Curepipe Experiment Station.

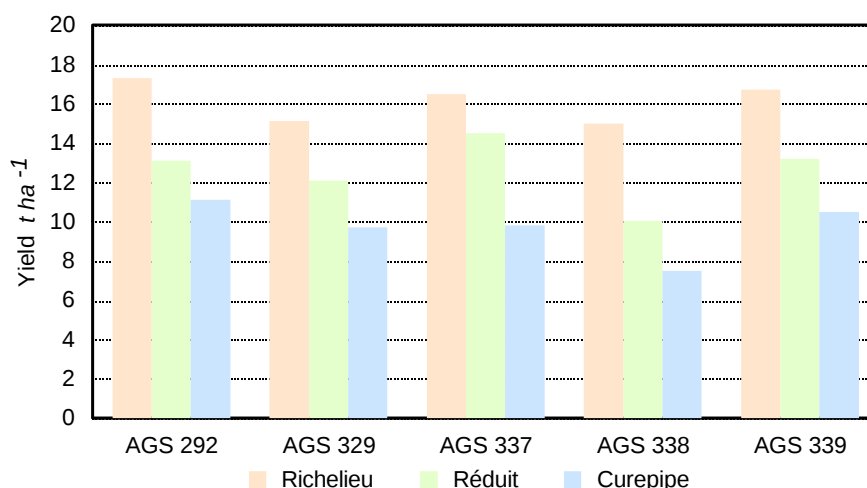
Table 4 Performance of 5 promising cultivars at three locations in February 1998.

Variety	Yield of fresh pods $t\ ha^{-1}$		
	Richelieu	Réduit	Curepipe
AGS 292	17.3	13.1	11.1 ^a
AGS 329	15.1	12.1	9.7 ^a
AGS 337	16.5	14.5	9.8 ^a
AGS 338	15.0	10.0	7.5 ^b
AGS 339	16.7	13.2	10.5 ^a
SE $\pm$	0.96	1.3	0.4

Means followed by same letters are not significantly different at $P = 0.05$

These observations are best-illustrated in **Figure 2** for all the cultivars. Although the yields among the five cultivars were not statistically significant at the 5 % level especially at Richelieu and Réduit the three cultivars AGS 292, 337 and 339 were the best performers. Their yields of fresh pods were consistently higher than the other cultivars under repeated field trials.

Figure 2 Yield of 5 promising cultivars at three locations in February 1998



Adaptability

The adaptability of vegetable soybean in more diverse sets of growing conditions was further investigated in trials conducted in Dubreuil, Curepipe, La Marie, Réduit, Trianon, Flacq, Richelieu, Saint Martin, Vacoas and Plaisance during different periods of the year in 1996, 1997 and 1998. These regions have different soil groups and families and a varying range of soil pH and precipitation rates. They also differ in terms of cation exchange capacities and nitrogen and organic matter content. These differences in soil characteristic and the yield of fresh pods recorded at various experimental sites are illustrated in **Table 5**.

The yield records show that the vegetable soybean crop is adapted to a wide range of soil conditions and even to low soil pH of Curepipe, La Marie and Dubreuil where it can also be grown under rainfed conditions. This adaptation to extremes of soil pH is also known in coastal podzolics and grey-black self-mulching soils where pH ranges from 4.0 to 8.5 (Rose 1991).

From the illustration, it can be noted that vegetable soybean can be grown throughout the year although better yields of fresh pods are achieved in the summer months.

Constraint to local production

Seed viability could be a limiting factor affecting the scope for large-scale local production of vegetable soybean. Dried seeds kept under ambient conditions at high temperature and high relative humidity lose viability in about 10 to 12 weeks. Seeds with moisture content of 9 % maintain their viability for only 9 to 12 months when stored in sealed polyethylene bags under controlled conditions (50 to 60 % relative humidity at about 18 °C).

In fact, soybean seeds are known to have an inherently short life span. They are physiologically mature and are at peak germination and vigour when they reach their maximum dry weight at 40 to 50 percent moisture content, about 65 to 75 days after flowering (Andrew 1996). Deterioration or ageing commences once the seed physiological maturity is attained. Storage cannot stop deterioration but it can minimise it to maintain viability until planting (Gregg).

Table 5 Fresh pod yields of vegetable soybean under varying soil type conditions.

Site	Soil type	C.EC <i>m.e</i>	Organic matter content %	Nitrogen content %	pH	Date planted	Yields obtained <i>t ha-1</i>
Dubreuil *	Humic Ferruginous latosol	20	6.9-10.4	0.2-0.34	4.3-5.9	Feb. 97	9 to 15
Curepipe	Latosolic brown Forest	30	12	0.3-0.8	5.0-6.3	Mar. 97	10.5 to14
						Sept. 97	12 to14
La Marie *	Latosolic brown Forest	30	12	0.3-0.8	5.0-6.3	Mar.98	11to13
Réduit	Low Humic latosol Réduit family	26	3.5-6	0.25-0.32	5.8-6.6	Nov.95	13 to16
						Aug.96	9 to 13
Trianon *	Low Humic latosol Réduit family	26	3.5-6	0.25-0.32	5.8-6.6	Apr.96	5to7
Flacq	Low humic latosol Bonne Mère family	24	5.0-6.0	0.24	6.0	May.96	9.5 to 13
						Mar.97	13 to23
						Mar.98	15 to17
Richelieu	Low humic latosol Richelieu family	28	3.2-5.2	0.2-0.29	6.5-7.3	Feb.98	15 to19
St. Martin	Low humic lactosol Richelieu family	28	3.2-5.2	0.2-0.29	6.5-7.3	Feb.98	15 to19
Vacoas	Latosolic reddish Prairie Médine family	36	6.6	0.32	6.0-7.1	Jan.97	14 to22
Plaisance land settlement	Latosolic reddish Prairie Mont Choisy family	37	7.7	0.34-0.5	6.0.-6.9	May-96	9to11

Source: Parish and Feillafe (1995)

* *Rainfed trials.*

CONCLUSION

Results obtained over the three-year investigation period are promising especially in terms of agronomic performance and adaptability to a wide range of growing conditions. The scope for promoting the local production of vegetable soybean looks favourable. Its potential as a diversification crop in the tea growing areas and in sugar cane interlines cannot be ignored. Response in terms of consumer's acceptance has also been positive because of its good taste and high nutritive value. Vegetable soybean can be considered as a crop with excellent future prospects.

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PRODUCTION AND VARIETAL EVALUATION OF CABBAGE AND CAULIFLOWER IN 1997

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ABSTRACT

Five varieties of cabbage were assessed at Réduit and Wooton from February to May 1997. Significant differences were obtained between the locations and the varieties tested. Yields were better at Réduit than at Wooton (an average marketable head weight of 1.47 Kg at Réduit compared to 0.47 Kg at Wooton). Three varieties of cauliflower were also evaluated at the same locations and there was a significant difference between the locations and also among the varieties tested.). Again yields at Réduit were better than at Wooton (the marketable average curd weight was 0.36 Kg at Réduit whereas it was 0.16 Kg at Wooton). A planting date trial with four varieties of cauliflower was run from June to December at Réduit. Significant differences among the varieties and the planting dates were found and are discussed.

Keywords: cabbages, *Brassica oleracea capitata*, cauliflowers, *Brassica oleracea botrytis*, variety trials

INTRODUCTION

The family Brassicaceae includes a number of vegetables of worldwide importance, and most of these are native to Europe, Middle East or Asia (Pierce 1987). Cauliflower and cabbage are the two most important crops of the brassica family, which are cultivated in Mauritius. The production statistics of the past ten years show that the area under production and the yield of cauliflower have increased by eight and ten times respectively (21 ha and 340 T in 1987 to 177 ha and 3425 T in 1996). As for cabbage the increase in area cultivated and yields was increased by three times (116 ha and 2675 T in 1987 to 340 ha and 7995 T in 1996) (Anon1987-1996). The seasonality of cauliflower restricts production to the cooler months of the year and thus causing a big fluctuation in price both at the beginning and at the end of the season. In 1996, the price of cauliflower ranged from Rs 14 /unit in August to Rs 40 /unit in January while that of cabbage ranged Rs 5 /unit in September to Rs 15 /unit in May.

Research on cabbage and cauliflower in Mauritius

In 1962 (Anon1962), three important varieties of cabbage Drumhead, Kopkool and Rapidity were compared with the local cabbage variety. The variety Drumhead had similar yield to the Local but had a shorter crop cycle of 2 months as compared to 3 months for the Local variety. Some heat tolerant varieties Springlight, summer autumn, KK cross and YR summer 50 were tested in a planting date trial from September to December 1980 (Anon 1980). Other cabbage varieties were included Libra, Ditmarscher Treub, Copenhagen Market 86, Jersey Wakefied and Koverno. No conclusive results were published for this trial (Anon 1981). However, in a variety trial against Local variety in 1985 (Anon 1985), varieties Riana, Rotan and Gloria showed significantly higher yields than the Local variety.

Research carried out in view of extending the production cycle of cauliflower dated since 1958 (Anon 1960). In 1962 (Anon 1962), results obtained showed that cauliflower could be produced beyond November in the uplands as long as precautionary measures were taken against droughts, insect pests and diseases. In 1980, the following heat tolerant varieties Snow Peak, Hsi-shu, Farmer's Early No. 3, Farmer's Early No. 2, and Snow King were tested at different planting dates from September to December on a monthly basis. Results showed that varieties Hsi-shu, Farmer's Early No. 2 and Farmer's Early No. 3 could be harvested as early as January (Anon 1980). However, this trial had to be terminated due to cyclone prevailing at that time. Other cauliflower varieties tested were Merchelse mero, Alpha prumira, Erfurtu motia, Hagon, Early Snow-ball X and Early Snow-ball Y (Anon 1981).

In a variety trial, results showed that Hsi-shu could produce a curd in October while for the same period the Local variety grew vegetatively (Anon 1981).

Justification of research work done

A rapid rural appraisal (RRA) exercise was conducted by AREU in June 1995 to carry out an inventory of the main problems encountered by crop producers. General concern has been expressed over the limited range of cabbage and cauliflower varieties currently available to growers. The lack of suitable varieties currently available to growers. The lack of suitable varieties of cauliflower remained a serious handicap to be overcome before production could be extended through the year (Anon 1995). In this context cabbage and cauliflower varieties were evaluated since 1995 at Wooton and Réduit. Work was also carried out to select cauliflower variety that can be used to extend the growing season.

MATERIALS AND METHODS

Cabbage and cauliflower variety trial

Five cabbage varieties Coastal boy, King globe, Bonnet, KK cross and Super master and three cauliflower varieties Kashmere, White Contessa and Local were evaluated in two localities (Réduit and Wooton) from February to May 1997. The seeds were treated against black rot by a hot water treatment at 50 °C for 15 minutes. They were then sown in small pots containing a mixture of farm yard manure (FYM), soil and sand in the ratio of 3:2:1 supplemented with triple super phosphate (TSP) and Muriate of potash (MOP). The seedlings were transplanted at the 4 to 5 leaf stage into holes measuring 25 x 25 x 20 cm. and were fertilised with 1kg FYM, 12 g TSP and 12 g MOP. A 2 x 5 and a 2 x 3 factorial design with 4 replicates was used for cabbage and cauliflower respectively. The plots measured 4.5 x 3.9 m and 6.0 x 4.75 m for cabbage and cauliflower respectively with 60 plants in each plot. Cabbage were planted in double rows at 75 cm apart. In any double rows, the interrow spacing was 60 cm while the intra-row spacing was 45 cm. Similarly to cauliflower, the distance between double rows was 90 cm. In the double rows, the interrow spacing was 75 cm while the intra-row was 60 cm. When the rainfall was lacking overhead irrigation was carried out at Réduit whereas manual watering was done at Wooton. The following parameters were recorded: fresh weight, head weight and circumference. Harvest lasted from 24.4 to 25.5.98 for cabbage and 15.4 to 26.5 for cauliflower. Soil samples were analysed for pH, total N % available P and K.

Planting date trials for cauliflower

A planting date trial was run from May to December 1997 at Réduit. Sowing of seeds was done every three weeks. The varieties Hsi-shu, White Contessa, Kashmere and Local were tested. The six different planting and transplanting dates is given below. Four varieties of cauliflower were evaluated at the following different planting dates

	Sowing	Transplanting
D 1	20 May 97	18 Jun 97
D 2	10 Jun 97	17 Jul 97
D 3	2 Jul 97	8 Aug 97
D 4	24 Jul 97	1 Sep 97
D 5	14 Aug 97	25 Sep 97
D 6	5 Sep 97	8 Oct 97

Fertilisation, preparation of seedlings and transplantation were similar to as in the experiment on variety evaluation of cauliflower.

RESULTS

Evaluation of cabbage varieties in two localities

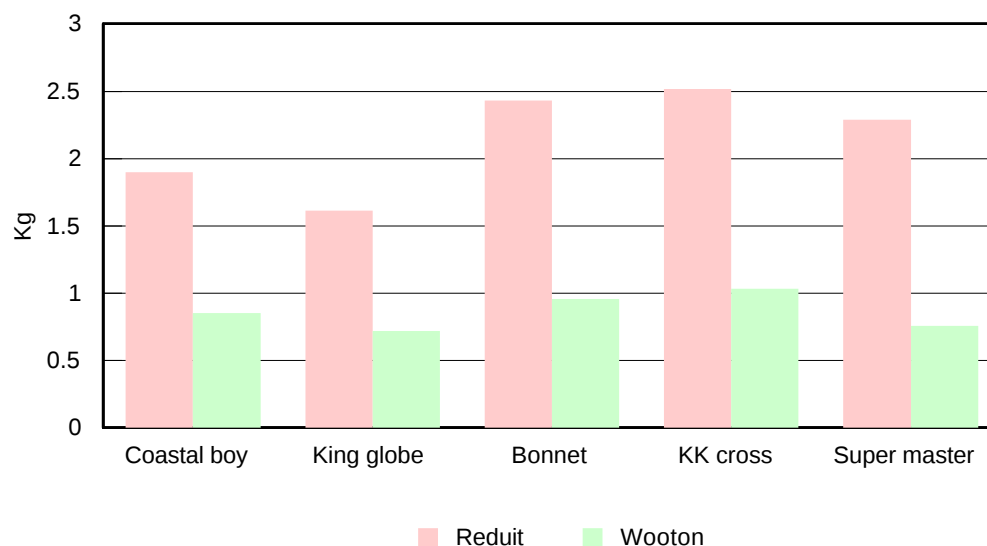
At Réduit, the mean temperature was 22.2 °C, ranging from 18.6 to 26.9 °C and at Wooton it was 21.2 °C, ranging from 18.8 to 23.7 °C.

Table 1 Performance of cabbage varieties in two localities (Réduit and Wooton)

Variety	Total yield Kg		Marketable yield Kg		Circumference Head m	
	Réduit	Wooton	Réduit	Wooton	Réduit	Wooton
Coastal Boy	1.90	0.85	1.25	0.43	0.55	0.38
King Globe	1.62	0.72	1.11	0.41	0.42	0.36
Bonnet	2.43	0.95	1.61	0.45	0.56	0.38
KK cross	2.52	1.03	1.77	0.63	0.69	0.48
Super master	2.29	0.75	1.59	0.46	0.63	0.42
Average	2.15	0.86	1.47	0.48	0.57	0.40
LSD ± 5%	0.57		0.30		0.06	
S.E	0.21		0.11		0.02	

There was a significant difference between the performances of the cabbage varieties grown at Réduit to those at Wooton (**Table 1**). Higher total and marketable yields as well as larger head circumferences were obtained at Réduit. The total yields of the cabbage varieties at Réduit (2.15 kg mean total yield) were significantly different from those at Wooton (0.86 kg mean total yield). The highest total yield was obtained with the variety KK cross (2.51 kg at Réduit and 1.03 kg at Wooton). The marketable yields were significantly different in both locations with a mean marketable head weight of 1.47 kg at Réduit and 0.47 kg at Wooton. The variety KK cross-performed best (1.77 kg head weight at Réduit and 0.45 kg at Wooton (**Figure 1**). The head circumferences were significantly different in both locations with variety KK cross giving the best performance (0.69m at Réduit and 0.48 m at Wooton).

Figure 1 Comparison of marketable yields of cabbage varieties in two localities



Evaluation of cauliflower varieties in two localities

At Réduit, the mean temperature was 23.6 °C, ranging from 20.5 to 26.8 °C and at Wooton it was 21.2 °C, ranging from 18.5 to 24 °C.

Table 2 Performance of cauliflower varieties at Réduit and Wooton

Variety	Total yield kg		Marketable yield kg		Circumference Head m	
	Réduit	Wooton	Réduit	Wooton	Réduit	Wooton
Kashmere	2.27	0.59	0.42	0.16	0.42	0.29
White contessa	1.70	0.62	0.47	0.18	0.46	0.30
Local	1.64	1.26	0.21	0.15	0.36	0.31
Average	1.87	0.82	0.37	0.16	0.41	0.30
LSD ± 5%	1.06		0.31		0.11	
S.E ±	0.25		0.07		0.03	

The performance of the cauliflower varieties at Réduit was significantly different from those at Wooton in terms of total and marketable yields as well as curd circumference. There was no significant difference among the varieties but their yields at Réduit were significantly different from those at Wooton (**Table2**). There was a significant difference among the varieties as well as their performance in both locations. The varieties Kashmere and White Contessa (0.42 and 0.47 kg curd weight respectively) performed better than the local variety (0.21 kg curd weight). There was no significant difference among the varieties however significant difference was obtained within the two localities. Variety White Contessa has a curd circumference of 0.46m at Réduit and 0.30m at Wooton.

Evaluation of cauliflower varieties at different planting dates

Table 3 Climatic data at the different planting dates at Réduit

Planting Date	Temperature °C	
	Mean of max.and min.	Range
D 1	18.7	14.2 - 23.2
D 2	19.4	15.3 - 23.5
D 3	19.4	15.2 - 23.7
D 4	20.0	16.5 - 23.5
D 5	23.2	19.0 - 27.5
D 6	22.2	19.6 - 25.4

The mean temperature increase from 18.7 °C at D1 in winter to 22.2 °C at D6 in summer(**Table 3**).

Table 4 Total yield of cauliflower varieties at different planting dates kg

Planting date	Variety				
	Hsi-shu	White contessa	Kashmere	Local	Average
D 1	0.97	1.00	1.96	1.32	1.31
D 2	0.91	1.27	1.91	1.94	1.51
D 3	0.99	0.93	1.66	1.72	1.33
D 4	1.00	1.21	1.82	1.58	1.40
D 5	0.95	1.15	1.12	0.95	1.04
D 6	0.99	0.67	0.98	0.71	0.84
Average	0.97	1.04	1.58	1.37	1.48

There was a significant difference among the planting dates. Planting date D 2 with transplantation taking place in mid-July gave the highest result with a mean total yield of 1.51 Kg (**Table 4**). There was also a significant difference among the varieties and the best variety Kashmere having a total head weight of 1.91 kg for planting date D 2. The performance of the varieties dropped when the summer months came in (**Figure. 2**). However variety White Contessa and Kashmere had total weight above 1.0 kg when transplanted in late September, D 5. The total yield was lowest at D 6 with 0.67kg for White Contessa.

Table 5 Marketable yield of cauliflower varieties at different planting dates Kg

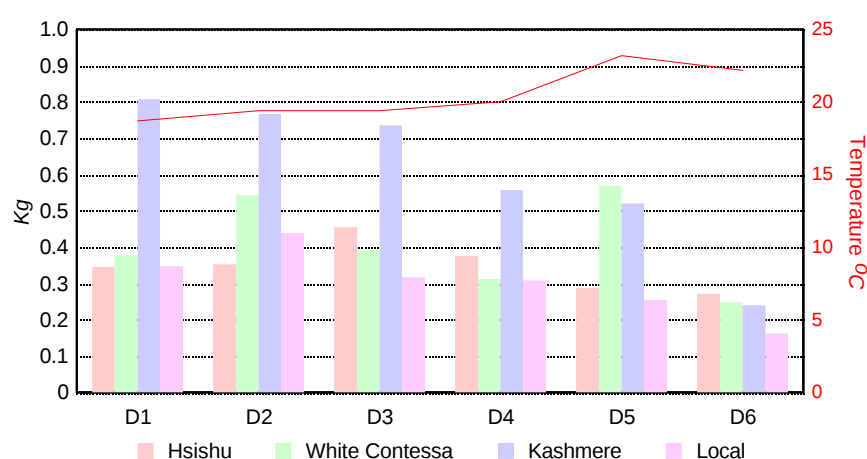
Planting Date	Variety				
	Hsi-shu	White Contessa	Kashmere	Local	Average
D 1	0.345	0.378	0.807	0.347	0.469
D 2	0.352	0.544	0.768	0.438	0.526
D 3	0.455	0.393	0.735	0.318	0.475
D 4	0.312	0.375	0.557	0.308	0.388
D 5	0.287	0.570	0.520	0.254	0.408
D 6	0.298	0.245	0.367	0.162	0.268
Average	0.342	0.418	0.626	0.305	0.507

LSD $\pm$ 5% = 0.055 S.E $\pm$ 0.026

There was a significant difference among the planting dates. The highest marketable yield (mean marketable curd weight of 0.520 kg) with the transplanting date of mid-August 1997, D5. There was also a significant difference among the varieties with a mean curd weight of 0.626 kg obtained with variety Kashmere. Similarly as for the total yields, the marketable yields dropped when the summer months came in. However, the varieties White Contessa and Kashmere gave reasonable curd weight of above 0.500 kg at the end of the season when transplanted in late September. The marketable yield was lowest at D 6 (i.e. when transplanted in October)

Curd circumference

Figure 2 Marketable yields of cauliflower varieties at different planting dates



There were significant differences in the curd circumferences among the planting dates as well as among the varieties tested. The best curd circumferences were obtained with the planting dates D 1, 0.457 m and D 2, 0.454 m whereas it was lowest at D 6, 0.369m (**Table 6**). The curd circumferences dropped as summer was coming in. The variety Kashmere gave the highest curd circumference over

the difference planting dates but varieties Hsi shu and White Contessa were better than Kashmere for D 6.

Table 6 Curd circumference of cauliflower varieties at different planting dates *m*

Planting Date	Variety				
	Hsi-shu	WhiteContessa	Kashmere	Local	Average
D 1	0.457	0.403	0.507	0.460	0.457
D 2	0.377	0.457	0.507	0.477	0.477
D 3	0.413	0.397	0.460	0.353	0.353
D 4	0.370	0.380	0.413	0.413	0.413
D 5	0.430	0.417	0.460	0.330	0.330
D 6	0.403	0.360	0.430	0.283	0.283
Average	0.403	0.402	0.463	0.386	0.385

LSD $\pm$ 5% = 0.045 S.E $\pm$ 0.01

DISCUSSION AND CONCLUSION

Performance of cabbage varieties in 2 localities-Réduit / Wooton

The different cabbage varieties performed better at Réduit where the mean temperature was 22.2 °C as compared to Wooton with mean temperature of 21.2 °C. At Wooton the pH as well as the N, P, K levels of the soil were low as compared to Réduit (**Table 7**). This is in accordance with the findings of (Askew and Smith 1996) who obtained lower yields with low pH and wide variations and excess of soil nutrient levels.

Table 7 Results of analysis of soil samples at Réduit and Wooton

Location	pH	Total N %	Available P Ppm	Available K me %
Réduit	5.5	0.37	183	0.82
Wooton	3.8	0.53	34	0.33

Performance of cauliflower varieties in 2 localities-Réduit / Wooton

As for cabbage, the results indicate that the cauliflower varieties performed better at Réduit than at Wooton. Small curds were obtained at Wooton in winter and this is in accordance with Carew and Thompson (1948) and Gauss and Taylor (1969) who found that too low temperature while the brassica plant is young may cause formation of “premature-curd” while slowing down the vegetative growth.

Planting date trial for cauliflower

The performance of varieties Hsi-shu and White Contessa did not drop drastically with the incoming of the summer months as compared to varieties Kashmere and Local (**Figure.2**). (Booij 1987, Salter1960 and Weibe1975) have reported that curd initiation in cauliflower is favoured by low temperature while at high temperature the crop develops vegetatively. Moreover at Wooton the pH (3.8) was low as compared to Réduit (5.5), which confirms findings of (Nath and Mohan 1993) who reported that low soil pH of 4.5 causes poor yield and curd quality.

Future research

Results obtained from these preliminary studies for cabbage and cauliflower have been used to set up new trials. The future work will thus consist of

- (1) Evaluation and identification of other summer varieties of cauliflower and cabbage adapted to different locations and determination of the optimum planting season of these varieties

- (2) Study the effect of the soil characteristics like pH and fertility on yield of cauliflower and cabbage
- (3) Determine the effect of transplant age on yield of cauliflower.

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QUALITY OF POTATO DURING STORAGE AT THREE TEMPERATURES

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ABSTRACT

The current practice of storing potato at 2-4 °C aims at preserving the physical appearance of the tubers by controlling sprouting, rotting and loss in weight. Low temperature storage is not only costly but also causes tubers to develop reducing sugars and hence become unsuitable for processing into French fries and crisps. Trials in 1990 and 1991 showed that tubers stored at 8-10 °C or at ambient temperature lost much weight because of excessive sprouting as from about 12 weeks. Storage at 2-4 °C, on the other hand, led to the formation of reducing sugars and to dark coloured French fries and crisps. The quality of tubers can be maintained for up to 12 weeks by storing at 8-10 °C, but beyond this period, it is necessary to control sprouting.

Keywords: *Solanum tuberosum*, potatoes, storage losses, keeping quality, storage, processing quality-temperature, Mauritius, reducing sugar, dry matter.

INTRODUCTION

Potato production in Mauritius is restricted to the cooler months, and fresh tubers are available from July to December. Tubers are stored at 2-4°C for use during the rest of the year. Cold storage aims at preserving the physical appearance of the tubers by controlling sprouting, rotting and loss in weight. It is expensive, and cooking and processing quality are adversely affected. Tubers stored at 2-4°C have a sweet taste when cooked because of high concentrations of reducing sugars. Crisps and French fries made from them darken on frying. The propensity of potato tubers to develop reducing sugars at low temperature is dependent on tuber maturity, environmental factors during tuber growth and varietal characteristics (Brown et al 1990). In Mauritius, freshly-harvested tubers of all varieties grown during the normal season have low reducing sugar contents (Wong Yen Cheong et al 1991). When tubers are stored at low temperatures, the levels of reducing sugars increase (Kolbe et al. 1995). The accumulation is rapid (Harkett 1972), the level at 1°C being 20 times that at 10 °C. When mature tubers are stored at relatively high temperatures, the concentration of reducing sugars remains low (Rubbi et al 1988). Storage above 10 °C may be satisfactory (Burton 1989), except that the quality of tubers deteriorates because of sprouting. Varieties are known to react differently to low temperature storage. For instance, when stored at 4-8°C, variety Shepody accumulated more sugars than Russet Burbank (Gichohi and Pritchard 1995). The objective of this research was to evaluate the quality of current varieties when stored at temperatures higher than 2-4°C

MATERIALS AND METHODS

Two trials were conducted. In the first, tubers of three commercial varieties, Delaware, Spunta and Up to date, were selected from a second season crop produced by a grower following cultural practices recommended by Govinden et al. (1986). After harvest in mid-November 1989, tubers were left at ambient temperature for a 15-day curing period. Healthy and undamaged tubers were placed in well-aerated nylon bags to constitute 14 samples of about 10 kg each per treatment. The samples were stored at 2-4°C, 8-10°C and at ambient temperature. In the cold store, the relative humidity was kept in the range of 90-95%. The samples were replicated twice in each store, but since there was little apparent variation between samples within a store, they were combined for analysis. Quality was assessed on separate samples at 3-week intervals for up to 21 weeks.

In the second trial, varieties Exodus and Spunta previously found to be the most acceptable for crisps and French-fries, (Wong Yen Cheong et al 1991) were used. They were stored at the same two low

temperatures. Tubers were harvested in mid-November 1990, and sampling and storage conditions were as in the first trial except that quality was assessed at 4-week intervals for up to 20 weeks. The samples were weighed at the beginning and on removal from the stores. The difference was recorded as overall loss in weight. Rotten tubers were then removed and the remaining tubers weighed again.

The date of sprouting was taken to be the date when over 25% of the tubers had sprouts more than 5mm long. Dry matter content was determined in terms of specific gravity (Burton 1989), measured by a potato hydrometer (Smith 1975). Reducing sugar content was measured by a modified version of the Luff-Schoorl method, (Burton, undated). In this method the maximum reducing sugar content that can be measured is 1 % fresh weight. This value is much higher than the threshold for crisps - i.e. 0.2% (Gould 1988) and for French-fries - i.e. 0.3% (Anon 1989). Crisps and French-fries were prepared and their colour measured as described by Wong Yen Cheong et al. (1991).

RESULTS AND DISCUSSION

In the first trial all three varieties behaved similarly. Overall losses in weight at 2-4°C and 8-10°C were similar and were $\leq 8\%$ (**Table 1**).

Table 1 Effects of storage temperature and duration on weight loss of three varieties in 1989-1990

Variety	Temp °C	Weeks in storage						
		3	6	9	12	15	18	21
% loss due to rotting								
Delaware	2- 4	0.5	0.5	2.0	1.5	0.0	0.5	6.5
	8-10	2.5	2.0	3.5	2.0	Discarded		
	ambient	18.0	13.5	10.0	24.5			
Spunta	2- 4	0.5	1.5	2.0	1.5	4.0	2.5	2.5
	8-10	0.5	1.5	2.5	2.0	Discarded		
	ambient	3.0	4.5	7.0	11.5			
Up to date	2- 4	0.5	2.0	3.5	2.0	3.0	2.5	2.0
	8-10	1.0	2.0	3.5	3.5	Discarded		
	ambient	4.5	7.5	10.0	12.0			
% overall loss								
Delaware	2- 4	1.0	0.5	2.5	3.0	0.5	1.0	8.0
	8-10	3.5	2.5	4.0	2.0	Discarded		
	ambient	26.0	30.5	27.0	44.5			
Spunta	2- 4	2.0	2.0	5.0	4.5	5.0	3.0	3.0
	8-10	3.5	2.0	6.0	3.5	Discarded		
	ambient	6.0	24.0	37.0	41.5			
Up to date	2- 4	1.0	3.5	4.0	3.0	4.0	3.5	3.5
	8-10	2.0	3.5	6.5	4.0	Discarded		
	ambient	7.5	10.5	18.0	17.0			

Overall losses were higher at ambient temperature and increased with time of storage. Losses at 8-10°C and at ambient temperature were not recorded after 12 weeks because all the tubers had to be discarded because of excessive sprouting, shrivelling and severe rotting, particularly at ambient temperature.

Overall weight losses were very low in the second experiment owing probably to better conditions at harvest, and no data are presented. Beukema and van der Zaag (1979) attributed weight losses during storage to losses in dry matter through respiration, water loss through evaporation, loss of sprouts and damage by fungal and bacterial diseases. Other losses, particularly in the tropics, are caused by pests (Hunt 1980). In the experiments, loss of sprouts during manipulation of the bags contributed to overall loss in weight in the post-sprouting period. Some soil, which adhered to the tubers, also contributed to overall loss, although most of this soil had been removed during the curing period. and pests, most probably rats, also caused important losses at ambient temperature.

Sprouting occurred in all three varieties after the 12th week at ambient temperature. In both experiments, only tiny sprouts were present on tubers stored at 8-10°C for 12 weeks; no observations were made after this time because of rotting. If tubers are to be stored for more than 12 weeks at 8-10°C, then sprouting must be controlled by chemical sprout inhibitors (Burton 1989). At 2-4°C, no sprouts were observed up to the end of the storage period.

In both experiments, specific gravity remained unchanged during storage at 2-4°C and 8-10°C (**Tables 2 & 3**). When tubers were stored at ambient temperature, specific gravity appeared to increase with time of storage, particularly in variety Spunta, but the trend was not consistent. The increase in specific gravity at ambient temperature could have occurred because in the store, there was no control of relative humidity and tubers could have lost water.

Table 2 Effects of storage temperature and duration on specific gravity, reducing sugars and colour rating of French fried potatoes.

Variety	Temp°C	Weeks in storage							
		0	3	6	9	12	15	18	21
Specific Gravity 1989 - 90									
Delaware	2-4	1.075	1.076	1.074	1.075	1.074	1.075	1.074	1.074
	8-10	1.075	1.076	1.076	1.074	1.075	discarded		
	ambient	1.075	1.076	1.076	1.077	1.079			
Spunta	2-4	1.069	1.072	1.072	1.070	1.069	1.071	1.072	1.070
	8-10	1.069	1.072	1.071	1.070	1.071	discarded		
	ambient	1.069	1.068	1.071	1.072	1.073			
Up to date	2-4	1.087	1.086	1.085	1.086	1.085	1.085	1.086	1.086
	8-10	1.087	1.087	1.083	1.084	1.087	discarded		
	ambient	1.087	1.087	1.086	1.086	1.086			
Reducing sugars concentration (% fresh weight of potato) 1989 - 1990									
Spunta	2-4	0.03	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	8-10	0.03	0.20	0.36	0.32	0.37	discarded		
	ambient	0.03	0.06	0.03	0.11	0.10			
Colour rating of French fries *									
Spunta	2-4	2	4	4	4	4	4	4	4
	8-10	2	2-3	2-3	2-3	2-3	discarded		
	ambient	2	2	2	2	2			

* French fry colour rating : 0 - pale, 4 - dark

There were no varietal differences in the effects of storage temperature on the concentration of reducing sugars and the colour of French-fries and crisps. There were no differences between the varieties with respect to the changes in reducing sugar concentration with time. Data for variety Spunta in experiment 1 and for variety Exodus in experiment 2 are presented in **Tables 2 & 3**. Variety Exodus which was found to be suitable for crisps owing to its low reducing sugar concentration in freshly harvested tubers and pale-coloured crisps (Wong Yen Cheong et al 1991), was no exception during storage at low temperature. All varieties had low concentrations of reducing sugars when initially placed in stores, which is in accordance with previous findings (Wong Yen Cheong et al 1991). Reducing sugar concentrations were lowest in tubers stored at ambient temperature. As expected, at 2-4°C, reducing sugar concentration increased rapidly to the maximum assessable value after 3 weeks in the first trial and 4 weeks in the second. They remained at this level for the remainder of the time in store.

Table 3 Effects of storage temperature and duration on specific gravity, Reducing sugars and crisp rating of French fried potatoes.

Variety	Temp°C	Weeks in storage					
		0	4	8	12	16	20
Specific Gravity 1990 - 91							
Exodus	2-4	1.079	1.080	1.079	1.079	1.078	1.079
	8-10	1.080	1.081	1.077	1.079	discarded	
Spunta	2-4	1.062	1.062	1.061	1.062	1.062	1.063
	8-10	1.062	1.062	1.061	1.063	discarded	
Reducing Sugars concentration (% fresh weight of potato) 1990 - 91							
Exodus	2-4	0.01	1.00	1.00	1.00	1.00	1.00
	8-10	0.01	0.24	0.31	0.33	discarded	
Colour rating of French crisps **							
Exodus	2-4	8	2	2	2	2	2
	8-10	8	5-6	5	5	discarded	

** Crisp colour rating : 9 - pale, 1 - dark (NB: reverse of French fry rating)

At 8-10°C, concentrations of reducing sugar ranged between 0.2 to 0.4% fresh weights in the first 12 weeks of storage. These levels were significantly higher than those observed at ambient temperature. Storage temperature had similar effects on the colour of French-fries and crisps as it did on concentrations of reducing sugars. Initial colour ratings of the two products were satisfactory, especially crisps from variety *Exodus* and French-fries from *Spunta*. French fries, and to a lesser extent, crisps made from tubers stored at 8-10°C, were moderately acceptable while those made from tubers stored at 2-4 °C became very dark.

The colours of French fries and crisps were associated with the levels of reducing sugars. These levels were within the acceptable limits for French-fries (Anon. 1989) but beyond those acceptable for crisps (Gould 1988). The processing quality of tubers stored at 8-10°C could be improved further by reducing the levels of reducing sugars through appropriate reconditioning of the tubers after removal from the stores (Burton 1989).

CONCLUSIONS

All varieties reacted in much the same way to storage temperature and duration. Although tubers kept at ambient temperature had low levels of reducing sugars, the practice is not acceptable because of losses due to rot, pests and sprouting and shrivelling of tubers. The current practice of storing potato at 2-4°C is satisfactory in that overall loss in weight and sprouting are controlled, but it leads to the formation of high concentrations of reducing sugars and hence to French-fries and crisps of poor quality. Fried products from tubers stored at 8-10°C were of moderately acceptable colour for the first 12 weeks of storage. An improvement in colour can be obtained if the tubers are properly reconditioned. At 8-10°C, storage for more than 12 weeks can only be envisaged if sprouting is controlled.

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POSTERS

ANTIBACTERIAL PROPERTIES OF PSIDIUM CATTLEIANUM SABINE EXTRACTS

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ABSTRACT

The plant Psidium Cattleianum Sabine commonly known as "Goyave de Chinerouge" is locally and regionally used for the treatment of chronic diarrhoea and dysentery. Total and ethyl acetate extracts obtained from young leaves of the plant were examined for antibacterial activities using a disc-susceptibility test. The results obtained indicate that ethyl acetate fractionated extracts seemed to have more effective antibacterial properties as demonstrated against Staphylococcus aureus, Staphylococcus epidermitis and Bacillus subtilis. Weaker activities were observed against Escherichia coli.

CURRENT STATUS OF RESEARCH IN ONION (*ALLIUM CEPA* L) IN MAURITIUS

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ABSTRACT

Research work conducted (1995-1997) in onion cultivation addressed alternative crop establishment methods like direct sowing using a pneumatic sower, multiseeded transplant, as compared to the traditional methods of using single transplant and from sets. The crop establishment from direct sowing is faster but requires good seedbed preparation. Multiseeded transplants gave significantly higher bulb yields than single transplants for all cultivars tested in trials carried out at Richelieu experimental Station. Forty-five short day onion cultivars were evaluated in trials conducted at Reduit and Richelieu Experimental Stations and on farms, for bulb yield, earliness and storability. Cultivars Roxa, Orient, Franciscana and Sivan produced significantly higher bulb yields. In onfarm trials, cultivars Savannah Sweet, HA 9, Sivan produced higher bulb yields which were not significantly different from the standard cultivar Yellow Dessex. Cultivars HA 944, Savannah Sweet and Ram 735 produced bulbs earlier than cultivar Yellow Dessex. Storage losses ranged from 15.4 to 84.3% for the different cultivars during the 16 weeks storage trial at Richelieu under ambient conditions. The prospects for producing onion bulbs earlier from sets were also investigated. Early onion production strategies for the local market involving green onion production, bulb production from sets from high yielding cultivars was tested in trials carried out at Richelieu Experimental Stations. Cultivar Local Red and Veronique produced 29 and 38 t/ha of green onions respectively over a 12 weeks crop cycle. Cultivars Savannah Sweet, HA 2000, and Mercedes produced significantly higher bulb yields than Local Red and Veronique.

EVALUATION OF FUNGICIDES FOR CONTROL OF CROWN ROT OF BANANA IN MAURITIUS

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ABSTRACT

The present investigation is part of the research components of a Mauritius Research Council (MRC) project on post harvest quality of banana. The paper highlights research on chemical control of crown rot of banana, a major post-harvest disease responsible for qualitative deterioration and serious economic losses in Mauritius. Crown rot attributed to Fusarium sp. alone and /or in combination with, Colletotrichum sp. and Verticillium sp. Was found to be the most predominant post-harvest disease encountered on banana in the local markets. Four fungicides, namely thiabendazole, benomyl, chlorothalonil and prochloraz were evaluated at two concentration levels for the control of the disease in Dwarf Cavendish variety and the experiment was repeated three times during year 1997. Effective control of crown rot with an extended shelf life was achieved with thiabendazole @ 500 and 1000 ppm and benomyl @ 250 and 500 ppm.

INFORMATION TECHNOLOGY IN AGRICULTURAL EXTENSION: SIRITELL, AN INFORMATION MANAGEMENT SYSTEM DEVELOPED AT THE MSIRI

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ABSTRACT

The Agricultural Information System (AIS) for sugar cane in Mauritius is often depicted as being composed of three main sub-systems, namely Sugar Cane Growers, Extension and Research. All three components of the AIS are sources of information and innovations. Since the Miller-Planters and the Owner-Planters of the Growers sub-system have differential access to resources, they do not always use the same channels for obtaining information and, in general, their information seeking behaviour is also different. The Mauritius Sugar Industry Research Institute (MSIRI) is responsible for research on sugar cane and its Extension and various research departments use different methods to disseminate information to various stakeholders of the AIS (e.g. Extension Agents, Agronomists and sugarcane growers). As an application of Information Technology (IT), SIRItell, a computerized information management system, is being developed by the MSIRI to improve the sharing of information with its partners of the AIS. SIRItell enables users to have access to technical and scientific information. It has definite advantages over traditional media such as printed material. However, the use of the Personal Computer (PC) as a communication medium, while being central to the user-friendliness of the application, is for the time being a factor, which limits its diffusion. In order to improve the relevance of SIRItell and to better assess the potential of IT for computer mediated communication (CMC), it is advocated that an audience-based approach involving participatory techniques should be encouraged. There is also a need to consider ways and means to improve the linkages within the AIS in order to make it more compatible with IT. A systems approach provides a useful framework to investigate how the components and interfaces of the system can be remodeled so as to “fit the AIS to the technology”

FRUIT FLY CONTROL IN MAURITIUS : PROGRESS ACHIEVED

S Permalloo , SI Seewooruthun, B Gungah, AR Soonoo

Agricultural services

ABSTRACT

An area wide control programme was implemented over 600km² in the North and North East of Mauritius. The bait application technique was used to bring down the fruit fly populations to very low levels, which was followed by the Male Annihilation technique to maintain populations at low levels. The effectiveness of the control methods was demonstrated by reduced adult catches in traps amounting to almost 100% in certain cases. Fruit infestation levels were reduced by at least 50to 75 %. The same techniques were mainly used for the containment of an exotic fruit fly in the southern regions of Mauritius with a view to its eventual eradication.

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